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(54) Title: **NOVEL MEANS AND METHODS FOR THE TREATMENT OF HEARING LOSS AND PHANTOM HEARING**

(57) Abstract: This invention relates to a method of identifying a modulator of an NADPH oxidase, whereby said modulator is suitable as a lead compound and/or as a medicament for the treatment and/or prevention of hearing loss and/or phantom hearing, the method comprising the steps of (a) contacting a test compound with a protein, wherein said protein (i) comprises or consists of the amino acid sequence of any one of SEQ ID NO: 1, 3 or 5, or (ii) is encoded by a nucleic acid comprising or consisting of the sequence of any one of SEQ ID NO: 2, 4, 6, 23 or 24, or (iii) is a fragment of the protein according to (i) or (ii) and exhibits NADPH oxidase activity, or (iv) has a sequence at least 75% identical with the protein according to (i) or (ii) or with the fragment according to (iii) and exhibits NADPH oxidase activity, and optionally with one or more NADPH oxidase subunits, under conditions allowing binding of said test compound to said protein or, if present, said subunit(s); (b) optionally determining whether said test compound binds to said protein or, if present, said subunit(s); and (c) determining whether (ca) said test compound, upon contacting in step (a); or (cb) said test compound, upon binding in step (b) modulates the expression and/or activity of said protein or, if present, said subunit(s). Also provided are pharmaceutical compositions, medical uses and diagnostic uses of compounds of the invention.

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Novel means and methods for the treatment of hearing loss and phantom hearing

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This invention relates to a method of identifying a modulator of an NADPH oxidase, whereby said modulator is suitable as a lead compound and/or as a medicament for the treatment and/or prevention of hearing loss and/or phantom hearing, the method comprising the steps of (a) contacting a test compound with a protein, wherein said
15 protein (i) comprises or consists of the amino acid sequence of any one of SEQ ID NO: 1, 3 or 5, or (ii) is encoded by a nucleic acid comprising or consisting of the sequence of any one of SEQ ID NO: 2, 4, 6, 23 or 24, or (iii) is a fragment of the protein according to (i) or (ii) and exhibits NADPH oxidase activity, or (iv) has a sequence at least 75% identical with the protein according to (i) or (ii) or with the
20 fragment according to (iii) and exhibits NADPH oxidase activity, and optionally with one or more NADPH oxidase subunits, under conditions allowing binding of said test compound to said protein or, if present, said subunit(s); (b) optionally determining whether said test compound binds to said protein or, if present, said subunit(s); and
(c) determining whether (ca) said test compound, upon contacting in step (a); or (cb)
25 said test compound, upon binding in step (b) modulates the expression and/or activity of said protein or, if present, said subunit(s). Also provided are pharmaceutical compositions, medical uses and diagnostic uses of compounds of the invention.

30 In this specification, a number of documents is cited. The disclosure of these documents, including manufacturer's manuals, is herewith incorporated by reference in its entirety.

Hearing impairment is a widespread and severe sensory deficit. It is the third most
35 prevalent major chronic disability in the over 65-year-old age group, but also found in

younger persons. Slightly more than 1 percent of people under the age of 17 have hearing loss, the prevalence rises to 12 percent between the ages of 45 and 64, to 24 percent between the ages of 65 and 74, and up to 39 percent for ages over 75. There are three major causes of hearing loss: noise-dependent hearing loss, drug-associated hearing loss and age-associated hearing loss. Interestingly, there appears to be a common mechanism to three major causes of hearing loss, namely destruction of sensory epithelium and cochlear neurons through reactive oxygen species. In terms of treatment, no efficient drug treatment or prophylaxis of hearing loss are available at this point and the only option at present is the use of hearing aids. This situation is further aggravated by the limited understanding of the molecular processes involved in hearing loss and the scarcity of suitable molecular targets for therapeutic intervention.

The inner ear is a highly complex structure involved in hearing and balancing. The conversion of sound into electrical signals occurs within the cochlea, in the organ of Corti, and the electrical signals are conducted by the axons of spiral ganglion neurons to the brain. The linear movement of the head is sensed by the otolith organs (utricle and saccule) and the rotation movements by the ampullas of the semicircular canals. The signals generated in the vestibular system are transmitted by the vestibular ganglion neurons to the central nervous system.

Hearing impairment due to loss of cochlear function occurs frequently, if not invariably over lifetime. Noise and ototoxic chemicals may lead to a precocious, rapid hearing loss, while age itself leads to a more insidious, chronic loss of hearing. Research over the last decades has identified reactive oxygen species (ROS¹) as the major factor mediating hearing loss [1]. ROS is generated within the cochlea after exposure to ototoxic drugs (e.g. cisplatin [2, 3], aminoglycoside antibiotics [3]) or to noise [4]. Signs of oxidative stress, such as DNA damage and lipid peroxidation, have been documented *in vivo* in response to those challenges [5, 6], as well as in cochlear aging

¹ The abbreviations used are: bp, base pair; DPI, diphenylene iodonium; DUOX, dual domain oxidase; 5-FU, 5-Fluorouracil; GAPDH, glyceraldehyde-3-phosphate dehydrogenase; gp91^{phox}, 91-kDa glycoprotein subunit of the phagocyte NADPH oxidase; NOX, NADPH oxidase; NOXA1, NOX activator 1; NOXO1, NOX organizer 1; PMA, phorbol 12-myristate 13-acetate; PCR, polymerase chain reaction; ROS, reactive oxygen species; RT-PCR, reverse transcription-PCR; SOD, superoxide dismutase.

[7]. The vestibular system is also damaged by ototoxic drugs [8, 9] in a process that includes excessive ROS production [10, 11].

While the role of oxidative stress in inner ear damage is well established, its source is poorly understood. A role of non-enzymatic generation of ROS by ototoxic compounds has been suggested [12]. The possibility that a superoxide-generating enzyme could be localized within the inner ear, and thereby account for the oxidative damage of this organ, has received little attention.

Over the last decade, it has been proven that the expression of superoxide-generating NADPH oxidases is not restricted to phagocytes. Beside the well-known catalytic subunit of the phagocyte NADPH oxidase, gp91^{phox}/NOX2 (for review see [13]), six other superoxide-producing enzymes have been identified in mammals [14, 15]. For most NOX and DUOX enzymes, a predominant tissue localization has been described, e.g. colon epithelium for NOX1 [16, 17], kidney cortex for NOX4 [18], lymphoid organs and testis for NOX5 [19], and the thyroid gland for DUOX1 and DUOX2 [20, 21]. For NOX3, with the exception of some very low level expression in the embryonic kidney [22], no convincing tissue localization had been found so far.

Our knowledge of the activation mechanisms of members of the NOX/DUOX family varies considerably among individual enzymes. NOX1 and gp91^{phox}/NOX2 are subunit-dependent enzymes that need to assemble with an activator subunit (NOXA1 and p67^{phox}, respectively) and an organizer subunit (NOXO1 and p47^{phox}, respectively) to generate superoxide [23-26]. NOX5, DUOX1 and DUOX2, on the other hand, have N-terminal Ca²⁺-binding motifs (EF-hand domains), and so far one of them, NOX5, has been shown to be activated by increased Ca²⁺ concentration [27]. The mechanism of NOX4 activation is less clear. There are indications that it might be a constitutively active enzyme [18].

Tinnitus, also referred to as phantom hearing, is a common and in some instances invalidating medical complaint. Presently, the pathophysiology of the disease is poorly understood and there is not proven causative treatment available. There is however evidence that reactive oxygen species might play a role in the pathophysiology of tinnitus (Neri S. Tinnitus and oxidative stress in a selected series

of elderly patients. Arch Gerontol Geriatr. 2002;35 Suppl:219-23) and there are at least some reports that suggest a beneficial effect of antioxidant medication such as Ginkgo extract on the course of the disease (e.g. Schneider D et al. Ginkgo biloba (Rokan) therapy in tinnitus patients and measurable interactions between tinnitus and vestibular disturbances. Int Tinnitus J. 2000;6(1):56-62). Thus, NOX3 might also be involved in the pathophysiology of tinnitus and the use of a NOX3 modulator or inhibitor is an interesting new concept for the treatment of tinnitus.

US-A1 20040001818 and WO-A1 0230453 describe methods of inhibiting angiogenesis, endothelial cell migration or endothelial cell proliferation using NADPH oxidase inhibitors.

EP-A2 1410798 describes a pharmaceutical composition comprising and uses of inhibitors of the production or the release of reactive oxygen metabolites (ROMs) and of compounds effective to scavenge ROMs. The uses are directed to the manufacture of a medicament for the treatment of Adult Respiratory Distress Syndrome (ARDS); ischemia or reperfusion injury, infectious disease, autoimmune or inflammatory diseases, and neurodegenerative diseases. Compounds effective to inhibit enzymatic ROM production or release comprise NADPH oxidase inhibitors.

EP-A2 0914821 relates to a method for diagnosis of atherosclerosis involving measurement of NADPH oxidase activity.

WO-A2 9719679 describes the use of NADPH oxidase inhibitors for the manufacture of a medicament for prevention of atherosclerosis.

US-A1 20040009901 relates to a method of treating a mammal having an autoimmune condition involving NADPH oxidase deficiency. Also, a method for identifying an agent that enhances NADPH oxidase activity is described.

WO-A2 02079224 relates to human peptides and proteins that are related to NADPH oxidase subfamily and methods for identifying modulators thereof. The proteins are described as being substantially similar to p47phox.

WO-A2 04007689 describes regulatory proteins for Nox enzymes, which are referred to as p41Nox proteins, and nucleic acid sequences encoding these proteins. Furthermore, a method for identifying a compound that modulates superoxide production is rescribed, the method involving administration of the protein. The envisaged medical indications relate to abnormal cell growth and proliferation and include cancer, prostatic hypertrophy and atherosclerosis.

NCBI Entrez protein database entry NP_056533 comprises the amino acid sequence of human NADPH oxidase 3 (NOX3). The sequence is 568 amino acids in length.

The database entry recites similarity to gp91phox.

In view of the limited understanding of processes leading to hearing loss and phantom hearing, the technical problem underlying the present invention was therefore the provision of means and methods for the development of drugs for treatment of hearing loss and phantom hearing.

Accordingly, this invention relates to a method of identifying a modulator of an NADPH oxidase, whereby said modulator is suitable as a lead compound and/or as a medicament for the treatment and/or prevention of hearing loss and/or phantom hearing, the method comprising the steps of (a) contacting a test compound with a protein, wherein said protein (i) comprises or consists of the amino acid sequence of any one of SEQ ID NO: 1, 3 or 5, or (ii) is encoded by a nucleic acid comprising or consisting of the sequence of any one of SEQ ID NO: 2, 4, 6, 23 or 24, or (iii) is a fragment of the protein according to (i) or (ii) and exhibits NADPH oxidase activity, or (iv) has a sequence at least 75% identical with the protein according to (i) or (ii) or with the fragment according to (iii) and exhibits NADPH oxidase activity, and optionally with one or more NADPH oxidase subunits, under conditions allowing binding of said test compound to said protein or, if present, said subunit(s); (b) optionally determining whether said test compound binds to said protein or, if present, said subunit(s); and (c) determining whether (ca) said test compound, upon contacting in step (a); or (cb) said test compound, upon binding in step (b) modulates the expression and/or activity of said protein or, if present, said subunit(s).

The term "modulator" designates a compound modulating the activity of a target

molecule, preferably by performing one or more of the following effects: (i) the transcription of the gene encoding the protein to be modulated is modulated, (ii) the translation of the mRNA encoding the protein to be modulated is modulated, (iii) the protein performs its biochemical function with modulated efficiency in presence of the modulator, and (iv) the protein performs its cellular function with modulated efficiency in presence of the modulator. It is understood that the term "modulator" includes inhibitors and activators at all regulatory levels mentioned above.

The term "NADPH oxidase" comprises any NADPH oxidase. It includes NOX enzymes such as NOX1, NOX2, NOX3, NOX4 and NOX5 as well as DUOX enzymes such as DUOX1 and DUOX2 (see references 13 to 27).

The term "lead compound" designates a compound which is a drug candidate and which may require chemical modifications in order to optimize its pharmacological properties and eventually become a drug to be formulated as a medicament. Methods of optimization are known in the art and further detailed below.

The term "hearing loss" according to the invention embraces drug-, noise- and age-related hearing loss. Age-related hearing loss is also referred to as presbycusis.

The term "phantom hearing", also known as "tinnitus", is a common and in some instances invalidating medical complaint.

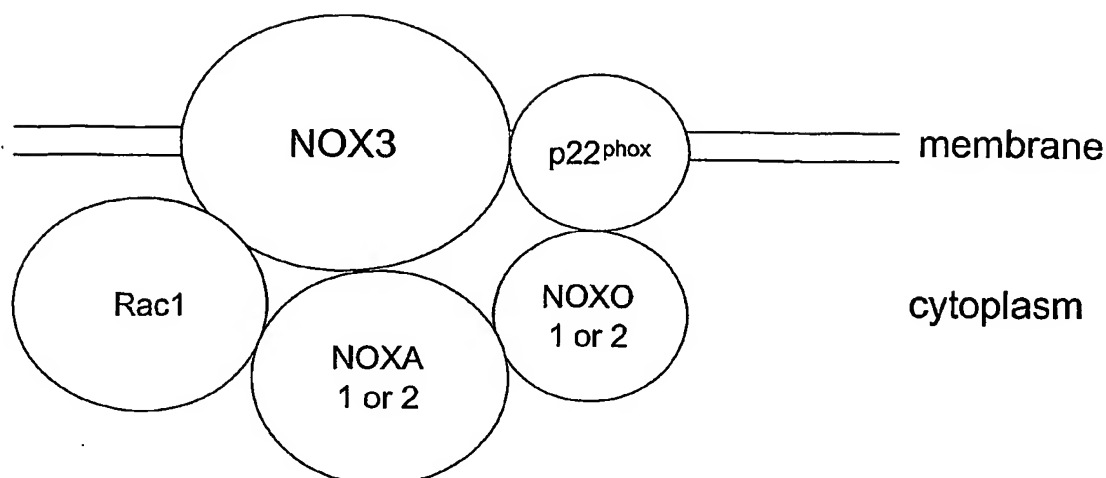
The term "protein" recited in the main claim extends to homologues having at least 75% sequence identity. Preferably, the sequence identity level is 80% or 85%, more preferred 90% or 95%, and yet more preferred 98% or 99%. For the purpose of determining the level of sequence identity, two nucleotide or protein sequences can be aligned electronically using suitable computer programs known in the art. Such programs comprise BLAST (Altschul et al. (1990), J. Mol. Biol. 215, 403-410), variants thereof such as WU-BLAST (Altschul & Gish (1996), Methods Enzymol. 266, 460-480), FASTA (Pearson & Lipman (1988), Proc. Natl. Acad. Sci. USA 85, 2444-2448) or implementations of the Smith-Waterman algorithm (SSEARCH, Smith & Waterman (1981), J. Mol. Biol. 147, 195-197). These programs, in addition to providing a pairwise sequence alignment, also report the sequence identity level (usually in percent identity) and the probability for the occurrence of the alignment by

chance (P-value). Programs such as CLUSTALW (Higgins et al. (1994), Nucleic Acids Res. 22, 4673-4680) can be used to align more than two sequences.

5 The optional presence of one or more NADPH oxidase subunits relates inter alia to embodiments, wherein not only modulators exerting their effect exclusively directly on the NADPH oxidase are to be identified, but also modulators which act by interfering with the association of the NADPH oxidase with said subunit(s) are to be identified. Such modulators may be compounds binding to regions of the NADPH oxidase and/or of the subunit(s) involved in subunit association. In other words, a test
10 compound identified by the method of the invention which interferes with association (e.g. binds to regions of the NADPH oxidase and/or of the subunit(s) involved in subunit association) is an example of a test compound according to the invention which either modulates expression and/or activity of the protein defined in the main embodiment or modulates the expression and/or activity of said subunit(s).

15 Also embraced by the invention is a method as defined above, wherein test compounds may be identified which modulate the expression and/or activity of both the protein defined in the main embodiment and said subunits.

20 In the following, the interactions of an NADPH oxidase with its subunits is exemplified for the NADPH oxidase 3 (NOX3). NOX3 activity requires the widely distributed membrane NOX subunit p22^{phox}. However, in the absence of further, viz. cytoplasmic subunits, no high level, but only low level ROS generation occurs. In contrast in the presence of the combination of one activator subunit (either NOXA1 or
25 p67^{phox}/NOXA2) and one organizer subunit (either NOXO1 or p47^{phox}/NOXO2) NOX3 is capable of generating high levels of ROS. In addition, the NOX3 activity most likely also involves the ubiquitous GTP-binding protein Rac. The interaction sites between the partners are depicted in the following scheme.



A key interaction is the binding of the activator domain of the activator subunits (amino acids 202-212 for hNOXA1 and amino acids 200-210 for hp67^{phox}/NOXA2) to NOX3. It is not clear whether there is a direct interaction of the organizer subunits with NOX3, but there is an indirect interaction with NOX3 through binding to p22^{phox} via the tandem SH3 domain (amino acids 158-217 and 233-289 for hNOXO1 and amino acids 156-216 and 226-286 for hp47^{phox}/NOXO2) and through binding to an SH3 domain of the activator subunit (amino acids 402-463 for hNOXA1 and amino acids 457-513 for hp67^{phox}/NOXA2) through its proline-rich region (amino acids 321-331 for hNOXO1 and 360-370 for hp47^{phox}/NOXO2). The precise site of interaction between NOX3 and p22^{phox}, as well as the sites of interaction of Rac1 with NOX3 and the activator subunits (NOXA1 or p67^{phox}) are not known. The table below provides a compilation of the interaction sites.

<u>binding region of the subunit</u>	<u>target</u>
activator region of activator subunit (aa 202-212 for hNOXA1 and aa 200-210 for hp67 ^{phox} /NOXA2)	NOX3
tandem SH3 domain of organizer subunit (aa 158-217 and aa 233-289 for hNOXO1 and aa 156-216 and 226-286 for hp47 ^{phox} /NOXO2)	p22^{phox}

proline-rich region of organizer subunit (aa 321-331 for hNOXO1 and 360-370 for hp47 ^{phox} /NOXO2)	SH3 domain of activator subunit (aa 402-463 for hNOXA1 and aa 457 – 513 for hp67 ^{phox} /NOXA2)
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The optional determination of binding test compounds in step (b) relates to any biophysical binding assay, which may be used to identify binding test molecules prior to performing the functional assay with the binding test molecules only. Suitable biophysical binding assays are known in the art and comprise fluorescence polarization (FP) assay, fluorescence resonance energy transfer (FRET) assay and surface plasmon resonance (SPR) assay. Step (b) is particularly advantageous if said biophysical assay is more amenable to high throughput than the functional assay.

Step (c) relates to the above mentioned functional assay. Determining whether a test compound, or a binding test compound, modulates the expression of a target protein may be accomplished by measuring the expression level. In a more preferred embodiment, the expression level to be determined is the mRNA expression level. Methods for the determination of mRNA expression levels are known in the art and comprise Real Time PCR, Northern blotting and hybridization on microarrays or DNA chips equipped with one or more probes or probe sets specific for transcripts encoding proteins of the NADPH oxidase family.

In another more preferred embodiment, the expression level to be determined is the protein expression level. The skilled person is aware of methods for the quantitation of proteins. Amounts of purified protein in solution can be determined by physical methods, e.g. photometry. Methods of quantifying a particular protein in a mixture rely on specific binding, e.g. of antibodies. Specific detection and quantitation methods exploiting the specificity of antibodies comprise immunohistochemistry (*in situ*) and surface plasmon resonance. Western blotting combines separation of a mixture of proteins by electrophoresis and specific detection with antibodies.

The present invention also relates to a method of identifying a modulator of an NADPH oxidase, whereby said modulator is suitable as a lead compound and/or as a

medicament for the treatment and/or prevention of hearing loss and/or phantom hearing, the method comprising the steps of (a) contacting a test compound with a protein, wherein said protein (i) comprises or consists of the amino acid sequence of any one of SEQ ID NO: 1, 3 or 5, or (ii) is encoded by a nucleic acid comprising or consisting of the sequence of any one of SEQ ID NO: 2, 4, 6, 23 or 24, or (iii) is a fragment of the protein according to (i) or (ii) and exhibits NADPH oxidase activity, or (iv) has a sequence at least 75% identical with the protein according to (i) or (ii) or with the fragment according to (iii) and exhibits NADPH oxidase activity, under conditions allowing binding of said test compound to said protein; and (b) determining whether said test compound, upon contacting in step (a) modulates the expression and/or activity of said protein.

The present invention also relates to a method of identifying a modulator of an NADPH oxidase, whereby said modulator is suitable as a lead compound and/or as a medicament for the treatment and/or prevention of hearing loss and/or phantom hearing, the method comprising the steps of (a) contacting a test compound with a protein, wherein said protein (i) comprises or consists of the amino acid sequence of any one of SEQ ID NO: 1, 3 or 5, or (ii) is encoded by a nucleic acid comprising or consisting of the sequence of any one of SEQ ID NO: 2, 4, 6, 23 or 24, or (iii) is a fragment of the protein according to (i) or (ii) and exhibits NADPH oxidase activity, or (iv) has a sequence at least 75% identical with the protein according to (i) or (ii) or with the fragment according to (iii) and exhibits NADPH oxidase activity, under conditions allowing binding of said test compound to said protein; (b) determining whether said test compound, upon contacting in step (a) modulates the expression and/or activity of said protein; and (c) performing clinical trials with said modulator.

In a preferred embodiment of the method of the invention, said contacting comprises contacting with one or more NADPH oxidase subunits, under conditions allowing binding of said test compounds to said subunit(s), and wherein said determining comprises determining whether said test compound modulates the expression and/or activity of said subunit(s).

In a further preferred embodiment the method further comprises, prior to step (b), the step of (b') determining whether said test compound binds to said protein or, if

present, said subunit(s), wherein said determining in step (b) is effected upon binding in step (b'). The method according to this preferred embodiment comprises both determining of whether a test compound, upon contacting in step (a), modulates expression and/or activity and the determining of whether a test compound, upon binding in step (b'), modulates expression and/or activity. The term "expression and/or activity" relate to, as defined herein above, the expression and/or activity of the protein as defined in the main embodiment and/or of said subunit(s).

Quantitation of the modulation of the activity of an NADPH oxidase may be effected by quantifying the reactive oxygen species production. Accordingly, said modulation preferably involves modulating the ROS production of said protein, and determining in step (c) comprises quantifying ROS production. Methods of quantifying ROS are known in the art and are further exemplified in Example 4 enclosed herewith.

The inventors for the first time demonstrated high-level expression of the NADPH oxidase NOX3 in the inner ear. Thereby, a protein suitable as a target for therapeutic intervention in hearing loss and phantom hearing is provided.

Vestibular and cochlear sensory epithelia develop from a common ectodermal thickening at the head region, called placode [34]. The otic placode also gives rise to the neurons that will form the inner ear ganglia [35]. The data presented in the Examples and Figures enclosed herewith suggest that the expression of NOX3 mRNA may follow this pattern.

Furthermore, the inventors demonstrated for the first time that NOX3 is a superoxide-generating enzyme. It is also demonstrated that the pattern of subunit- and stimulus-dependence that is distinct from other known NOX family NADPH oxidases. NOX3, as opposed to NOX1 and NOX2, produces low levels of superoxide upon PKC activation without the need of subunits. While the activation of phagocyte NADPH oxidase is thought to occur through PKC-dependent phosphorylation of p47^{phox} [13], this, obviously, cannot be the mechanism of the subunit-independent activation of NOX3. At this point, there are numerous possible pathways how PKC might activate NOX3 (e.g. direct phosphorylation of NOX3, activation of the small GTPase protein Rac1, or changes in the lipid environment). The subunit-independent ROS-

generation by NOX3 is of low level in the transfected cells. Given the localization of NOX3 in the inner ear, close to or within highly ROS-sensitive cells, it is tempting to speculate that low, rather than high level superoxide generation is the default mode of NOX3 function.

5

However, NOX3 activity can be massively enhanced by known NOX organizer and regulator/activator subunits. Searches of mouse and human genomic databases suggest that there are probably no other close homologues of p47^{phox} and p67^{phox} than NOXO1 and NOXA1, respectively. Thus, if NOX3 functions in a subunit-dependent manner *in vivo*, it would have to use subunits of other NOX enzymes. Based on PCR data shown in Figure 2, NOX3 could potentially interact with NOXA1 and/or p47^{phox} in the inner ear. However, it cannot be excluded that, under specific circumstances or in a very limited number of cells, other NOX subunits may also be expressed in the inner ear.

10

Therefore, in a preferred embodiment, said NADPH oxidase subunit(s) is/are the activating subunit(s) NOXA1 and/or p67^{phox}/NOXA2, and/or the organising subunit(s) NOXO1 and/or p47^{phox}/NOXO2.

20 In a further preferred embodiment said protein and, if present, said subunit(s) is/are comprised in a membrane preparation. Membrane preparations according to the invention may be membrane fractions obtained, for example, by centrifugation upon cell disruption. Alternatively, said membrane preparation is obtained by reconstituting the protein(s) according to the main embodiment with membrane- or micelle-forming
25 amphiphilic lipids.

In a further preferred embodiment said protein and, if present, said subunit(s) is/are comprised in a cell transfected with a nucleic acid encoding said protein. This embodiment relates to a cellular screen.

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In a further preferred embodiment of the method of the invention, said protein and, if present, said subunit(s) is/are comprised in a non-human animal. This embodiment relates to an *in vivo* screen. While less amenable to high throughput, the *in vivo* screen offers the advantage of the assessment of the disease state of the non-

human animal. Accordingly, in a more preferred embodiment, the modulation of ROS production involves improving the hearing of said animal and determining in step (c) involves quantifying said hearing.

- 5 In a further preferred embodiment, prior to said contacting, (a') an ototoxic agent and/or an agent increasing the activity and/or the expression of said protein or subunit(s), is brought into contact with said protein or subunit(s) is/are administered to said cell or said animal. Administration of an ototoxic agent and/or an agent increasing the activity and/or the expression of said protein or subunit(s) may be
10 used as a means of modelling (at the cellular level), or inducing/enhancing (at the organismic level) the disease or disease-related conditions.

Interestingly, while there is almost no literature on the physiological function of ROS in the inner ear, there is a considerable number of studies on the pathological effect
15 of excessive ROS production in this organ (for reviews see [1] and [4]). It has been shown in several publications that specific ototoxic drugs (such as platinum derivatives or aminoglycoside antibiotics) lead to accumulation of ROS in both the cochlea [3] and the vestibular system [8, 11, 36], and noise trauma has been demonstrated to be a prominent cause of ROS production in the cochlea [37]. A
20 permanent increase of ROS concentration, in turn, leads primarily to the death of sensory epithelial cells, and, to a lesser extent, to the death of innervating neurons [1]. Based on the surprising observations presented herein and relating to its localization and its capacity to generate ROS, NOX3 is likely to be a major source of ROS in the inner ear. The unexpected observation that cisplatin markedly enhances
25 NOX3-dependent superoxide production, evokes the possibility that NOX3 is a mediator of cisplatin-dependent ototoxicity. Time course and dose-response of the cisplatin-dependent NOX3 activation is compatible with the time course [2] and dose-response [38] of cisplatin toxicity to inner ear sensory cells.

- 30 In a more preferred embodiment, said ototoxic agent is selected from the group consisting of salicylates, non-steroidal antiinflammatories, antibiotics, diuretics, cytostatics, quinine derivatives and gastroprotective drugs.

Salicylates include Aspirine and methyl-salicylates.

Non-steroidal antiinflammatories include diclofenac, etocolac, fenprofen, ibuprofen,

indomethacin, naproxen, piroxicam and sulindac.

Preferred antibiotics are aminoglycosides such as amikacin, gentamycin, kanamycin, neomycin, netilmicin, streptomycin and tobramycin. Further preferred antibiotics include erythromycin, vancomycin, minocycline, polymixin B, amphotericin B and capreomycin.

Exemplary diuretics according to the invention are bendroflumethazide, bumetadine, chlorthalidone, ethacrynic acid and furosemide.

Cytostatics, or antineoplastic drugs according to the invention include bleomycine, bromocriptine, carboplatinum, cisplatin, methotrexate, nitrogen mustard, vinblastin and vincristine.

Quinine derivatives, being used as antimalarial and antiarrhythmic drugs, include chloroquine phosphate, quinacrine hydrochloride and quinine sulphate.

Misoprostol is among the envisaged gastroprotective drugs.

In a preferred embodiment of the method of the invention, said NADPH oxidase is NOX3. In a further preferred embodiment said NADPH oxidase is the protein defined in claim 1.

In a further preferred embodiment, the method of the invention further comprises the step of formulating said modulator with a pharmaceutically acceptable carrier. By "pharmaceutically acceptable carrier" is meant a non-toxic solid, semisolid or liquid filler, diluent, encapsulating material or formulation auxiliary of any type.

More preferred, and prior to said formulating, the affinity, specificity and/or pharmacological properties of the modulator are optimized and/or clinical trials are performed with said modulator or the optimized modulator.

Accordingly, the present invention also relates to a method of identifying a modulator of an NADPH oxidase, whereby said modulator is suitable as a lead compound and/or as a medicament for the treatment and/or prevention of hearing loss and/or phantom hearing, the method comprising the steps of (a) contacting a test compound with a protein, wherein said protein (i) comprises or consists of the amino acid sequence of any one of SEQ ID NO: 1, 3 or 5, or (ii) is encoded by a nucleic acid comprising or consisting of the sequence of any one of SEQ ID NO: 2, 4, 6, 23 or 24, or (iii) is a fragment of the protein according to (i) or (ii) and exhibits NADPH oxidase

activity, or (iv) has a sequence at least 75% identical with the protein according to (i) or (ii) or with the fragment according to (iii) and exhibits NADPH oxidase activity, under conditions allowing binding of said test compound to said protein; (b) determining whether said test compound, upon contacting in step (a) modulates the expression and/or activity of said protein; and (c) performing clinical trials with said modulator.

Methods for the optimization of the pharmacological properties of compounds identified in screens, generally referred to as lead compounds, are known in the art and comprise a method of modifying a compound identified as a lead compound to achieve: (i) modified site of action, spectrum of activity, organ specificity, and/or (ii) improved potency, and/or (iii) decreased toxicity (improved therapeutic index), and/or (iv) decreased side effects, and/or (v) modified onset of therapeutic action, duration of effect, and/or (vi) modified pharmacokinetic parameters (resorption, distribution, metabolism and excretion), and/or (vii) modified physico-chemical parameters (solubility, hygroscopicity, color, taste, odor, stability, state), and/or (viii) improved general specificity, organ/tissue specificity, and/or (ix) optimized application form and route by (i) esterification of carboxyl groups, or (ii) esterification of hydroxyl groups with carbon acids, or (iii) esterification of hydroxyl groups to, e.g. phosphates, pyrophosphates or sulfates or hemi succinates, or (iv) formation of pharmaceutically acceptable salts, or (v) formation of pharmaceutically acceptable complexes, or (vi) synthesis of pharmacologically active polymers, or (vii) introduction of hydrophilic moieties, or (viii) introduction/exchange of substituents on aromates or side chains, change of substituent pattern, or (ix) modification by introduction of isosteric or bioisosteric moieties, or (x) synthesis of homologous compounds, or (xi) introduction of branched side chains, or (xii) conversion of alkyl substituents to cyclic analogues, or (xiii) derivatisation of hydroxyl group to ketals, acetals, or (xiv) N-acetylation to amides, phenylcarbamates, or (xv) synthesis of Mannich bases, imines, or (xvi) transformation of ketones or aldehydes to Schiff's bases, oximes, acetals, ketals, enolesters, oxazolidines, thiozolidines or combinations thereof; said method optionally further comprising the steps of the above described methods.

The various steps recited above are generally known in the art. They include or rely on quantitative structure-action relationship (QSAR) analyses (Kubinyi, "Hansch-Analysis and Related Approaches", VCH Verlag, Weinheim, 1992), combinatorial

biochemistry, classical chemistry and others (see, for example, Holzgrabe and Bechtold, Deutsche Apotheker Zeitung 140(8), 813-823, 2000).

Individuals to be selected for said clinical trials comprise healthy individuals, individuals with a disposition or at risk to develop hearing loss or phantom hearing and patients suffering from hearing loss or phantom hearing. Hearing loss is understood to comprise drug-, noise- and age-related hearing loss.

Moreover, the present invention also relates to a pharmaceutical composition comprising: (a) an antibody, aptamer, or a fragment or derivative thereof binding specifically the protein defined in the main embodiment; (b) an antisense nucleic acid, an siRNA, or a ribozyme binding specifically a nucleic acid encoding said protein; (c) a iodonium derivative and/or a substituted catechol such as apocynin; (d) a compound comprising the fragment of SEQ ID NO: 11 from position 202 to position 212, the fragment of SEQ ID NO: 11 from position 402 to position 463, the fragment of SEQ ID NO: 15 from position 200 to position 210, the fragment of SEQ ID NO: 15 from position 457 to position 513, the fragment of SEQ ID NO: 7 from position 158 to position 217, the fragment of SEQ ID NO: 7 from position 233 to position 289, the fragment of SEQ ID NO: 7 from position 321 to position 331, the fragment of SEQ ID NO: 19 from position 156 to position 216, the fragment of SEQ ID NO: 19 from position 226 to position 286, the fragment of SEQ ID NO: 19 from position 360 to position 370; and/or (e) a nucleic acid comprising a sequence encoding any of the fragments according to (d). The fragments according to (d) are regions of the sequences of the respective SEQ ID NOs known or expected to be involved in subunit association.

Said compounds according to (d) may furthermore comprise a cell-penetrating peptide. The term "cell-penetrating peptide" relates to a peptide which is capable of entering into cells. This capability may be exploited for the delivery of fragments defined in (d) to cells.

For example, said compounds may be peptides or polypeptides comprising both a fragment as defined in (d) above and a cell-penetrating peptide. Alternatively, other means of functionally linking a fragments as defined in (d) and a cell-penetrating peptide are envisaged. Preferably, said compounds comprising both a fragment as defined in (d) above and a cell-penetrating peptide act as dominant negative cell-

permeating inhibitors.

Said cell-penetrating peptides according to the invention include Tat-derived cell-penetrating peptides [46, 47], Antennapedia peptides or penetratins [48, 49] such as the peptide having the sequence Arg-Gln-Ile-Lys-Ile-Trp-Phe-Gln-Asn-Arg-Arg-Met-Lys-Trp-Lys-Lys (SEQ ID NO: 25), peptides derived from HSV-1 VP22 [50], transportans [51], MAP peptides [52] such as the peptide with the sequence KLALKLALKALKAAALKLA (SEQ ID NO: 26), signal sequence-based cell-penetrating peptides (NLS) [53], hydrophobic membrane translocating sequence (MTS) peptides [53] and arginine-rich transporters for drugs. According to an overview of cell-penetrating peptides is provided in [45], CPPs are divided into two classes: the first class consists of amphipathic helical peptides, such as transportan and model amphipathic peptide (MAP), where lysine (Lys) is the main contributor to the positive charge, while the second class includes arginine (Arg)-rich peptides, such as TAT and Antp or penetratin.

The nucleic acids according to (e) include the sequences with the SEQ ID NOs: 12, 16, 8 and 20 as well those fragments thereof which comprise a sequence encoding any of the fragments according to (d). Said nucleic acid may optionally comprise a sequence encoding a cell-penetrating peptide.

Also embraced by the present invention are pharmaceutical compositions comprising fragments of proteins orthologous or homologous to hNOXA1, hNOXO1, hp67phox/NOXO2 or hp67phox/NOXA2, whereby said fragments align with the fragments of hNOXA1, hNOXO1, hp47phox/NOXO2 or hp67phox/NOXA2 recited under (d), as are pharmaceutical compositions comprising nucleic acids encoding these aligning fragments. It is understood that these pharmaceutical compositions are considered equivalents of the above described embodiment directed to pharmaceutical compositions. Said orthologous or homologous proteins include the respective murine proteins, i.e., proteins having an amino acid sequence set forth in any one of SEQ ID NO: 13, 17, 9 or 21. The nucleic acids encoding the latter are set forth in SEQ ID NO: 14, 18, 10 and 22.

Two nucleotide or protein sequences can be aligned electronically using suitable computer programs known in the art. Such programs comprise BLAST (Altschul et al. (1990), J. Mol. Biol. 215, 403-410), variants thereof such as WU-BLAST (Altschul & Gish (1996), Methods Enzymol. 266, 460-480), FASTA (Pearson & Lipman (1988), Proc. Natl. Acad. Sci. USA 85, 2444-2448) or implementations of the Smith-

Waterman algorithm (SSEARCH, Smith & Waterman (1981), J. Mol. Biol. 147, 195-197). These programs, in addition to providing a pairwise sequence alignment, also report the sequence identity level (usually in percent identity) and the probability for the occurrence of the alignment by chance (P-value). Programs such as CLUSTALW
5 (Higgins et al. (1994), Nucleic Acids Res. 22, 4673-4680) can be used to align more than two sequences.

Furthermore embraced by the present invention are pharmaceutical compositions comprising (a) peptidomimetic compound(s) which has been obtained by using any of the fragments according to (d) as a lead compound.

10 Pharmaceutical compositions comprising a nucleic acid according to (e) and/or the above described equivalents thereof are also envisaged to be used for gene therapy. For this purpose, the nucleic acid may be part of an expression, a gene transfer or gene targeting vector. Gene therapy, which is based on introducing therapeutic
15 genes into cells by ex-vivo or in-vivo techniques is one of the most important applications of gene transfer. Transgenic mice expressing a neutralizing antibody directed against nerve growth factor have been generated using the "neuroantibody" technique; Capsoni, Proc. Natl. Acad. Sci. USA 97 (2000), 6826-6831 and Biocca, Embo J. 9 (1990), 101-108. Suitable vectors, methods or gene-delivering systems for in-vitro or in-vivo gene therapy are described in the literature and are known to the
20 person skilled in the art; see, e.g., Giordano, Nature Medicine 2 (1996), 534-539; Schaper, Circ. Res. 79 (1996), 911-919; Anderson, Science 256 (1992), 808-813, Isner, Lancet 348 (1996), 370-374; Muhlhauser, Circ. Res. 77 (1995), 1077-1086; Onodua, Blood 91 (1998), 30-36; Verzeletti, Hum. Gene Ther. 9 (1998), 2243-2251; Verna, Nature 389 (1997), 239-242; Anderson, Nature 392 (Supp. 1998), 25-30;
25 Wang, Gene Therapy 4 (1997), 393-400; Wang, Nature Medicine 2 (1996), 714-716; WO 94/29469; WO 97/00957; US 5,580,859; US 5,589,466; US 4,394,448 or Schaper, Current Opinion in Biotechnology 7 (1996), 635-640, and references cited therein. The nucleic acid molecules according to (e) may be designed for direct introduction or for introduction via liposomes, viral vectors (e.g. adenoviral, retroviral),
30 electroporation, ballistic (e.g. gene gun) or other delivery systems into the cell. Additionally, a baculoviral system can be used as eukaryotic expression system for the nucleic acid molecules of the invention. The introduction and gene therapeutic approach should, preferably, lead to the expression of a fragment according to (d) of the invention, whereby said expressed fragment is particularly useful in the

treatment, amelioration and/or prevention of hearing loss and/or phantom hearing.

Said antibody, which is monoclonal antibody, polyclonal antibody, single chain antibody, or fragment thereof that specifically binds said peptide or polypeptide also including bispecific antibody, synthetic antibody, antibody fragment, such as Fab, a F(ab₂)', Fv or scFv fragments etc., or a chemically modified derivative of any of these (all comprised by the term "antibody"). Monoclonal antibodies can be prepared, for example, by the techniques as originally described in Köhler and Milstein, *Nature* 256 (1975), 495, and Galfré, *Meth. Enzymol.* 73 (1981), 3, which comprise the fusion of mouse myeloma cells to spleen cells derived from immunized mammals with modifications developed by the art. Furthermore, antibodies or fragments thereof to the aforementioned peptides can be obtained by using methods which are described, e.g., in Harlow and Lane "Antibodies, A Laboratory Manual", CSH Press, Cold Spring Harbor, 1988. When derivatives of said antibodies are obtained by the phage display technique, surface plasmon resonance as employed in the BIAcore system can be used to increase the efficiency of phage antibodies which bind to an epitope of the peptide or polypeptide of the invention (Schier, *Human Antibodies Hybridomas* 7 (1996), 97-105; Malmberg, *J. Immunol. Methods* 183 (1995), 7-13). The production of chimeric antibodies is described, for example, in WO89/09622. A further source of antibodies to be utilized in accordance with the present invention are so-called xenogenic antibodies. The general principle for the production of xenogenic antibodies such as human antibodies in mice is described in, e.g., WO 91/10741, WO 94/02602, WO 96/34096 and WO 96/33735. Antibodies to be employed in accordance with the invention or their corresponding immunoglobulin chain(s) can be further modified using conventional techniques known in the art, for example, by using amino acid deletion(s), insertion(s), substitution(s), addition(s), and/or recombination(s) and/or any other modification(s) known in the art either alone or in combination. Methods for introducing such modifications in the DNA sequence underlying the amino acid sequence of an immunoglobulin chain are well known to the person skilled in the art; see, e.g., Sambrook (1989), loc. cit..

The term "monoclonal" or "polyclonal antibody" (see Harlow and Lane, (1988), loc. cit.) also relates to derivatives of said antibodies which retain or essentially retain their binding specificity. Whereas particularly preferred embodiments of said derivatives are specified further herein below, other preferred derivatives of such

antibodies are chimeric antibodies comprising, for example, a mouse or rat variable region and a human constant region.

The term "scFv fragment" (single-chain Fv fragment) is well understood in the art and preferred due to its small size and the possibility to recombinantly produce such fragments.

Preferably, the antibody, aptamer, fragment or derivative thereof according to the invention specifically binds the target protein, (poly)peptide or fragment or epitope thereof whose presence or absence is to be monitored.

The term "specifically binds" in connection with the antibody used in accordance with the present invention means that the antibody etc. does not or essentially does not cross-react with (poly)peptides of similar structures. Cross-reactivity of a panel of antibodies etc. under investigation may be tested, for example, by assessing binding of said panel of antibodies etc. under conventional conditions (see, e.g., Harlow and Lane, (1988), loc. cit.) to the (poly)peptide of interest as well as to a number of more or less (structurally and/or functionally) closely related (poly)peptides. Only those antibodies that bind to the (poly)peptide/protein of interest but do not or do not essentially bind to any of the other (poly)peptides which are preferably expressed by the same tissue as the (poly)peptide of interest, are considered specific for the (poly)peptide/protein of interest and selected for further studies in accordance with the method of the invention.

In a particularly preferred embodiment of the method of the invention, said antibody or antibody binding portion is or is derived from a human antibody or a humanized antibody.

The term "humanized antibody" means, in accordance with the present invention, an antibody of non-human origin, where at least one complementarity determining region (CDR) in the variable regions such as the CDR3 and preferably all 6 CDRs have been replaced by CDRs of an antibody of human origin having a desired specificity. Optionally, the non-human constant region(s) of the antibody has/have been replaced by (a) constant region(s) of a human antibody. Methods for the production of humanized antibodies are described in, e.g., EP-A1 0 239 400 and WO90/07861.

The term "aptamer" as used herein refers to DNA or RNA molecules that have been selected from random pools based on their ability to bind other molecules. Aptamers

have been selected which bind nucleic acid, proteins, small organic compounds, and even entire organisms. A database of aptamers is maintained at <http://aptamer.icmb.utexas.edu/>.

- 5 An antisense nucleic acid according to the invention is a nucleic acid molecule complementary to a nucleic acid molecule encoding a protein according to the main embodiment which may be used for the repression of expression of said protein. The construction of small interfering RNAs (siRNAs) (see, e.g. Zamore Nat Struct Biol 2001, 8(9):746-50 or Tuschl T. CHEMBIOCHEM. 2001, 2:239-245) or of appropriate
10 ribozymes (see, e.g., EP-B1 0 291 533, EP-A1 0 321 201, EP-A2 0 360 257) which specifically cleave the (pre)-mRNA of a gene comprising a nucleic acid encoding said protein are also suitable for the repression of expression. The techniques underlying said repression of expression are well known in the art. Selection of appropriate target sites and corresponding ribozymes can be done as described for example in
15 Steinecke et al. (Methods in Cell Biology (1995) 50:449-460). Standard methods relating to antisense technology have also been described (Melani et al., Cancer Res. (1991) 51:2897-2901). Said nucleic acid molecules may be chemically synthesized or transcribed by an appropriate vector containing a chimeric gene which allows for the transcription of said nucleic acid molecule in the cell. Such nucleic acid
20 molecules may further contain ribozyme sequences as described above.

Iodonium derivatives or, more specifically, arylodonium compounds include diphenylene iodonium (DPI, also referred to as iodoniumdiphenyl or iodonium biphenyl), di-2-thienyliodonium (also referred to as iodonium thiophene) and
25 phenoxaiodonium. These compounds act as arylating agents and directly and irreversibly inhibit NOX enzymes.

Apocynin (4-hydroxy-3-methoxy-acetophenone) is a methoxy-substituted catechol and exerts its effect on NOX enzymes through the inhibition of subunit assembly.

Also embraced by the present invention are pharmaceutical compositions comprising
30 (i) naphthoquinones such as plumbagin, acetylshikonin; (ii) inhibitors of HMG-CoA reductase including statins such as lovastatin, simvastatin, atorvastatin; (iii) gliotoxin; (iv) phenothiazines such as phenothiazine, trifluoperazine, and/or (v) a derivative of any one of (i) to (v).

Plumbagin is a naphthoquinone derived from *Plumbago Zeylanica* (Chitrak, an indian

medicinal plant).

Gliotoxin is a metabolite of pathogenic fungi (*Aspergillus* and *Candida* spp) and has been implicated in infectious pathways. It exhibits immunosuppressive action and antitumor activity and inhibits activation process of NOX2 (Yoshida et al., 2000) and the assembly of the enzyme (Tsunawaki et al., 2004). It is available from Sigma.

Statins are inhibitors of HMG-CoA. They decrease plasma cholesterol and block rac-1 dependent activation of NADPH oxidases (Maack et al. 2003). Furthermore, they inhibit myristoylation of rac.

Trifluoperazine is an inhibitor of PKC/calmodulin and prevents the activation of NADPH oxidases (Seifert and Scachtele, 1988, Holland et al., 2000).

The term derivative relates to compounds having the same core or backbone structure while one or more of the substituents are modified, for example by replacing a methyl group with a trifluoromethyl group. These modifications are such that the biological/pharmacological activity is not substantially altered. Said activity may be monitored by the assays disclosed herein.

The present invention also relates to a pharmaceutical composition consisting of (a) ortho-methoxy-substituted catechols such as apocynin, acetosyringone, vanillin, vanillic acid, syringaldehyde, syringic acid; and (b) a pharmaceutically acceptable carrier, excipient or diluent.

Also provided by the present invention is a pharmaceutical composition comprising (a) an ototoxic agent; and (b) a compound selected from the group consisting of: (i) an antibody, aptamer, or a fragment or derivative thereof binding specifically the protein defined in claim 1; (ii) an antisense nucleic acid, an siRNA, or a ribozyme binding specifically a nucleic acid encoding said protein; (iii) a compound comprising the fragment of SEQ ID NO: 11 from position 202 to position 212, the fragment of SEQ ID NO: 11 from position 402 to position 463, the fragment of SEQ ID NO: 15 from position 200 to position 210, the fragment of SEQ ID NO: 15 from position 457 to position 513, the fragment of SEQ ID NO: 7 from position 158 to position 217, the fragment of SEQ ID NO: 7 from position 233 to position 289, the fragment of SEQ ID NO: 7 from position 321 to position 331, the fragment of SEQ ID NO: 19 from position 156 to position 216, the fragment of SEQ ID NO: 19 from position 226 to position 286, the fragment of SEQ ID NO: 19 from position 360 to position 370, wherein said

compound may furthermore comprise a cell-penetrating peptide; (iv) a nucleic acid comprising a sequence encoding any of the fragments according to (c), wherein said nucleic acid may optionally comprise a sequence encoding a cell-penetrating peptide; (v) arylodonium compounds such as diphenylene iodonium (DPI), di-2-thienyliodonium, phenoxaodonium; (vi) naphthoquinones such as plumbagin, acetylshikonin; (vii) inhibitors of HMG-CoA reductase including statins such as lovastatin, simvastatin, atorvastatin; (viii) gliotoxin; (ix) phenothiazines such as phenothiazine, trifluoperazine, and/or (x) a derivative of any one of (v) to (ix). Said ototoxic agent may be any agent detailed herein above. Preferably, said ototoxic agent is a medicament, wherein said medicament causes ototoxicity as a side effect. Therefore, and in view of the disclosure of the mechanism of ototoxicity in this application, a combination therapy with a medicament with ototoxic side effect and an inhibitor of the protein defined in the main embodiment is provided. Also provided is the use of an ototoxic agent and of a compound as defined in (b) above for the manufacture of pharmaceutical composition, wherein said compound as defined in (b) prevents, alleviates or cures the ototoxic effect of said ototoxic agent.

In a preferred embodiment of said pharmaceutical composition, said ototoxic agent is an antibiotic.

In a more preferred embodiment of said pharmaceutical composition, said ototoxic agent is an aminoglycoside antibiotic, preferably gentamycin. This type of combination therapy is particularly envisaged for those regions or countries where aminoglycoside antibiotics such as gentamycin, owing to their low cost, are widely used.

The present invention also relates to the use of a modulator of the protein defined in the main embodiment for the preparation of a pharmaceutical composition for the treatment and/or prevention of hearing loss and/or phantom hearing, wherein said modulator is selected from the group consisting of (a) an antibody, aptamer, or a fragment or derivative thereof binding specifically said protein; (b) an antisense nucleic acid, an siRNA, or a ribozyme binding specifically a nucleic acid encoding said protein; (c) a known modulator of NOX3 and/or NADPH oxidases and/or electron transport proteins; (d) a compound comprising the fragment of SEQ ID NO:

11 from position 202 to position 212, the fragment of SEQ ID NO: 11 from position 402 to position 463, the fragment of SEQ ID NO: 15 from position 200 to position 210, the fragment of SEQ ID NO: 15 from position 457 to position 513, the fragment of SEQ ID NO: 7 from position 158 to position 217, the fragment of SEQ ID NO: 7 from position 233 to position 289, the fragment of SEQ ID NO: 7 from position 321 to position 331, the fragment of SEQ ID NO: 19 from position 156 to position 216, the fragment of SEQ ID NO: 19 from position 226 to position 286, the fragment of SEQ ID NO: 19 from position 360 to position 370; (e) a nucleic acid comprising a sequence encoding any of the fragments according to (d); and (f) a modulator identified by the method of any one of claims 1 to 13. The fragments according to (d) are regions of the sequences of the respective SEQ ID NOs known or expected to be involved in subunit association. Said compounds according to (d) may furthermore comprise a cell-penetrating peptide. The term "cell-penetrating peptide" is defined herein above.

15 The nucleic acids according to (e) include the sequences with the SEQ ID NOs: 12, 16, 8 and 20 as well those fragments thereof which comprise a sequence encoding any of the fragments according to (d). Said nucleic acid may optionally comprise a sequence encoding a cell-penetrating peptide.

Also embraced by the present invention are uses of fragments of proteins orthologous or homologous to hNOXA1, hNOXO1, hp47phox/NOXO2 or hp67phox/NOXA2, whereby said fragments align with the fragments of hNOXA1, hNOXO1, hp47phox/NOXO2 or hp67phox/NOXA2 recited under (d), as are uses of nucleic acids encoding these aligning fragments. It is understood that these uses are considered equivalents of the above described embodiment. Said orthologous or homologous proteins include the respective murine proteins, i.e., proteins having an amino acid sequence set forth in any one of SEQ ID NO: 13, 17, 9 or 21. The nucleic acids encoding the latter are set forth in SEQ ID NO: 14, 18, 10 and 22.

Furthermore embraced by the present invention are uses of (a) peptidomimetic compound(s) which has been obtained by using any of the fragments according to (d) as a lead compound.

Uses of a nucleic acid according to (e) and/or of the above described equivalents thereof are also envisaged for gene therapy.

The present invention also relates to the use of a cisplatin and/or hydrogen hexachloroplatinate for the preparation of a pharmaceutical composition for the treatment and/or prevention of tinnitus. Cisplatin and hydrogen hexachloroplatinate are activators of the protein defined the main embodiment. Surprisingly, in many incidences of tinnitus a positive response to a treatment with compounds known to induce oxidative stress in the inner ear is observed.

Also provided is a method of diagnosing hearing loss and/or phantom hearing and/or an individual's disposition or risk to develop said loss and/or said phantom hearing, comprising the steps of: (a) determining (a) polymorphism(s) in a NOX3 gene or cDNA and/or in a gene or cDNA encoding an NADPH oxidase subunit in a sample obtained from said individual; and (b) associating said polymorphism(s) with a disease state or disposition state. Preferably, said sample is a blood sample. Preferably, said NOX3 gene comprises or consists of the sequence set forth in SEQ ID NO: 23 or 24. Preferably said NOX3 cDNA (or equivalently mRNA) comprises or consists of the sequence set forth in SEQ ID NO: 2, 4 or 6. Preferably said cDNA encoding an NADPH oxidase subunit comprises or consists of the sequence set forth in any one of SEQ ID NOs: 8, 10, 12, 14, 16, 18, 20 or 22.

The term "polymorphism", or "nucleotide polymorphism" refers to the occurrence of one or more different nucleotides or bases at a given location on a chromosome. Usually, polymorphisms are distinguished from mutations based on their prevalence. Sometimes a threshold of 1% prevalence in a population of individuals is considered for separating polymorphisms (more frequent) from mutations (less frequent). A single nucleotide polymorphism (SNP) is a polymorphism of a single nucleotide or base. The SNP database maintained at NCBI (<http://www.ncbi.nlm.nih.gov/SNP/>) divides SNPs into SNPs in the proximity of a known locus and such that are 5' further away than 2 kb from the most 5' feature of a gene and 3' further away than 500 bases from the most 3' feature of a gene. SNPs in the proximity of a known locus are further divided into SNPs occurring at an mRNA location and such that do not. SNPs occurring at an mRNA location comprise coding and non-coding SNPs.

It is understood that the term "polymorphism(s) in a NOX3 gene and/or in a gene encoding an NADPH oxidase subunit" embraces polymorphisms in exons, introns and regulatory regions such as promoters. Polymorphisms in exons may be

determined or analysed using genomic DNA or cDNA (or equivalently mRNA). Polymorphisms in introns or regulatory regions such as promoters may be determined or analysed using cDNA (or equivalently mRNA).

- 5 Said associating of polymorphism(s) with a disease state or disposition state refers to classifying of individuals and patients. The term "classifying" refers to the assignment of individuals or patients to two or more groups or classes. In other words, individuals, previously unclassified, get labelled by their respective class. The assigned class label may refer to parameters used for classification, e.g.
- 10 polymorphisms, or may refer to parameters not used for classification because their values are not known beforehand, e.g. fast or slow response to therapy. In the first case, class discovery methods, e.g. clustering may be applied, whereas in the second case predictive classification methods are used. Classification may be done manually by a trained person or by a computer program provided with the values of
- 15 the parameters used for class distinction. Patients have to give informed consent. Data have to be handled and kept secret in accordance with national laws.

- The present invention also provides the use of a compound binding to the protein defined in the main embodiment or to a NADPH oxidase subunit for the preparation
- 20 of a diagnostic composition for the diagnosis of hearing loss and/or phantom hearing and/or an individual's disposition or risk to develop said loss and/or said phantom hearing, wherein said compound is selected from the group consisting of (a) an antibody, aptamer, or a fragment or derivative thereof binding specifically said protein; and (b) a known modulator of NOX3 and/or NADPH oxidases and/or electron
- 25 transport proteins.

- In a preferred embodiment of the use according to the invention, said known modulator is selected from the group consisting of iodonium derivatives, substituted catechols such as apocynin, platinum derivatives and palladium derivatives.

- 30 Known modulators to be used for the preparation of a pharmaceutical composition according to the invention are selected from the group consisting of (i) aryl-iodonium compounds such as diphenylene iodonium (DPI), di-2-thienyliodonium, phenoxaiodonium; (ii) ortho-methoxy-substituted catechols such as apocynin,

acetosyringone, vanillin, vanillic acid, syringaldehyde, syringic acid; (iii) naphthoquinones such as plumbagin, acetylshikonin; (iv) inhibitors of HMG-CoA reductase including statins such as lovastatin, simvastatin, atorvastatin; (v) gliotoxin; (vi) phenothiazines such as phenothiazine, trifluoperazine; and (vii) a derivative of
5 any one of (i) to (vi). Said known modulators act as inhibitors of the protein defined in the main embodiment.

Known modulators to be used for the preparation of a diagnostic composition according to the invention are selected from the known modulators to be used for the
10 preparation of a pharmaceutical composition and cisplatin and hexachloroplatinate as well as derivatives thereof. Cisplatin and hexachloroplatinate bind and activate the protein defined in the main embodiment and are therefore specifically envisaged for the manufacture of a diagnostic composition.

15 Cisplatin, as demonstrated by the inventors, is a preferred platinum derivative which modulates NOX3 activity. The platinum derivative hydrogen hexachloroplatinate and palladium derivatives are known to modulate the activity of NOX2 (phagocyte NADPH oxidase). In both cases, there are indications that modulation is a direct effect on the NOX enzymes.

20 Also envisaged is the use of a compound binding to a nucleic acid encoding the protein defined in the main embodiment or an NADPH oxidase subunit for the preparation of a diagnostic composition for the diagnosis of hearing loss and/or phantom hearing and/or an individual's disposition or risk to develop said loss and/or
25 said phantom hearing, wherein said compound is a nucleic acid complementary to said nucleic acid and at least 15 nucleotides in length. This embodiment is directed to oligonucleotide probes for the detection of genomic DNA or mRNA. With regard to genomic DNA, also the detection and distinction of polymorphisms is envisaged.

30 Preferably, said compound is detectably labelled.

More preferred, said diagnosis to be performed involves imaging of the human or animal body.

In a preferred embodiment of the method or the use of the invention, said animal is a rodent. More preferred, said rodent is mouse or rat.

5 In a preferred embodiment of the method or the use of the present invention, said modulator is an inhibitor.

The term "inhibitor" designates a compound lowering the activity of a target molecule, preferably by performing one or more of the following effects: (i) the transcription of the gene encoding the protein to be inhibited is lowered, (ii) the translation of the mRNA encoding the protein to be inhibited is lowered, (iii) the protein performs its
10 biochemical function with lowered efficiency in presence of the inhibitor, and (iv) the protein performs its cellular function with lowered efficiency in presence of the inhibitor.

15 Compounds falling in class (i) include compounds interfering with the transcriptional machinery and/or its interaction with the promoter of said gene and/or with expression control elements remote from the promoter such as enhancers. Compounds of class (ii) comprise antisense constructs and constructs for performing RNA interference well known in the art (see, e.g. Zamore (2001) or Tuschl (2001)).
20 Compounds of class (iii) interfere with molecular function of the protein to be inhibited, in case of an NADPH oxidase with its enzymatic activity and/or its capability to associate with NADPH oxidase subunits. Accordingly, active site binding compounds, in particular compounds capable of binding to the active site of any NADPH oxidase, are envisaged, as are compounds interfering with the association of
25 NADPH oxidase with said subunits. More preferred are compounds specifically binding to an active site of NADPH oxidase. Also envisaged are compounds binding to or blocking substrate binding sites of NADPH oxidase. Class (iv) includes compounds which do not necessarily directly bind to NADPH oxidase, but still interfere with NADPH oxidase activity, for example by binding to and/or inhibiting the
30 function or inhibiting expression of members of a pathway which comprises NADPH oxidase. These members may be either upstream or downstream of NADPH oxidase within said pathway.

In a preferred embodiment, the inhibitor is a low molecular weight compound. Low molecular weight compounds are compounds of natural origin or chemically synthesized compounds, preferably with a molecular weight between 100 and 1000, more preferred between 200 and 750, and even more preferred between 300 and 600.

The efficiency of the inhibitor can be quantitized by comparing the level of activity in the presence of the inhibitor to that in the absence of the inhibitor. For example, as an activity measure may be used: the change in amount of mRNA formed, the change in amount of protein formed, the change in amount of substrate converted or product formed, and/or the change in the cellular phenotype or in the phenotype of an organism.

In a preferred embodiment, the level of activity is less than 90%, more preferred less than 80%, 70%, 60% or 50% of the activity in absence of the inhibitor. Yet more preferred are inhibitors lowering the level down to less than 25%, less than 10%, less than 5% or less than 1% of the activity in absence of the inhibitor.

The present invention also relates to a nucleic acid (i) comprising or consisting of the sequence of SEQ ID NO: 6, or (ii) encoding a protein comprising or consisting of the sequence of SEQ ID NO: 5, or (iii) encoding a fragment of the protein according to (ii), wherein said fragment exhibits NADPH oxidase activity, or (iv) encoding a protein having a sequence at least 95% identical with the protein according to (ii) or with the fragment according to (iii) and exhibiting NADPH oxidase activity.

Preferably, said protein having at least 95% sequence identity with the protein according to (ii) or with the fragment according to (iii), has 98% or 99% identity with said protein or fragment.

An alternative embodiment of the invention relates to a vector comprising the above defined nucleic acid.

The vector of the present invention may be, e.g., a plasmid, cosmid, virus, bacteriophage or another vector used e.g. conventionally in genetic engineering, and may comprise further genes such as marker genes which allow for the selection of said vector in a suitable host cell and under suitable conditions.

Furthermore, the vector of the present invention may, in addition to the nucleic acids of the invention, comprise expression control elements, allowing proper expression of the coding regions in suitable hosts. Such control elements are known to the artisan and may include a promoter, a splice cassette, translation initiation codon, translation and insertion site for introducing an insert into the vector. Preferably, the nucleic acid of the invention is operably linked to said expression control sequences allowing expression in eukaryotic or prokaryotic cells.

Many suitable vectors are known to those skilled in molecular biology, the choice of which would depend on the function desired and include plasmids, cosmids, viruses, bacteriophages and other vectors used conventionally in genetic engineering. Methods which are well known to those skilled in the art can be used to construct various plasmids and vectors; see, for example, the techniques described in Sambrook (1989), loc. cit., and Ausubel, Current Protocols in Molecular Biology, Green Publishing Associates and Wiley Interscience, N.Y. (1989), (1994). Alternatively, the nucleic acids and vectors of the invention can be reconstituted into liposomes for delivery to target cells. According to the invention relevant sequences can be transferred into expression vectors where expression of a particular (poly)peptide/protein is required. Typical cloning vectors include pBscpt sk, pGEM, pUC9, pBR322 and pGBT9. Typical expression vectors include pTRE, pCAL-n-EK, pESP-1, pOP13CAT.

Furthermore, a protein encoded by said nucleic acid is provided.

The present invention furthermore relates to host containing an aforementioned vector or an aforementioned nucleic acid, or an aforementioned protein. Said host may be produced by introducing said vector or nucleic acid into a host cell which upon its presence in the cell mediates the expression of a protein encoded by the nucleic acid of the invention or comprising a nucleic acid or a vector according to the invention wherein the nucleic acid and/or the encoded (poly)peptide/protein is foreign to the host cell.

By "foreign" it is meant that the nucleic acid and/or the encoded (poly)peptide/protein is either heterologous with respect to the host, this means derived from a cell or organism with a different genomic background, or is homologous with respect to the host but located in a different genomic environment than the naturally occurring

counterpart of said nucleic acid. This means that, if the nucleic acid is homologous with respect to the host, it is not located in its natural location in the genome of said host, in particular it is surrounded by different genes. In this case the nucleic acid may be either under the control of its own promoter or under the control of a heterologous promoter. The vector or nucleic acid according to the invention which is present in the host may either be integrated into the genome of the host or it may be maintained in some form extrachromosomally. In this respect, it is also to be understood that the nucleic acid of the invention can be used to restore or create a mutant gene via homologous recombination.

The host can be any prokaryote or eukaryotic cell, such as a bacteria, an insect, fungal, plant or animal cell.

The term "prokaryote" is meant to include all bacteria which can be transformed or transfected with a DNA or RNA molecules for the expression of a protein of the invention. Prokaryotic hosts may include gram negative as well as gram positive bacteria such as, for example, *E. coli*, *S. typhimurium*, *Serratia marcescens* and *Bacillus subtilis*. The term "eukaryotic" is meant to include yeast cells, cells of higher plant, insect cells and preferably mammalian cells. Depending upon the host employed in a recombinant production procedure, the protein encoded by the nucleic acid of the present invention may be glycosylated or may be non-glycosylated. A nucleic acid of the invention can be used to transform or transfect the host using any of the techniques commonly known to those of ordinary skill in the art. Furthermore, methods for preparing fused, operably linked genes and expressing them in, e.g., mammalian cells and bacteria are well-known in the art (Sambrook (1989), loc. cit.).

Preferably, said host is a cell. More preferred, the host is a human cell or human cell line.

Alternatively, said host is a transgenic non-human animal.

A method for the production of a transgenic non-human animal, for example transgenic mouse, comprises introduction of a nucleic acid or vector according to the invention into a germ cell, an embryonic cell, stem cell or an egg or a cell derived therefrom. The non-human animal can be used in accordance with a screening method of the invention described herein. Production of transgenic embryos and

screening of those can be performed, e.g., as described by A. L. Joyner Ed., *Gene Targeting, A Practical Approach* (1993), Oxford University Press. The DNA of the embryonal membranes of embryos can be analyzed using, e.g., Southern blots with an appropriate probe. A general method for making transgenic non-human animals is described in the art, see for example WO 94/24274. For making transgenic non-human organisms (which include homologously targeted non-human animals), embryonal stem cells (ES cells) are preferred. Murine ES cells, such as AB-1 line grown on mitotically inactive SNL76/7 cell feeder layers (McMahon and Bradley, *Cell* 62: 1073-1085 (1990)) essentially as described (Robertson, E. J. (1987) in *Teratocarcinomas and Embryonic Stem Cells: A Practical Approach*. E. J. Robertson, ed. (Oxford: IRL Press), p. 71-112) may be used for homologous gene targeting. Other suitable ES lines include, but are not limited to, the E14 line (Hooper et al., *Nature* 326: 292-295 (1987)), the D3 line (Doetschman et al., *J. Embryol. Exp. Morph.* 87: 27-45 (1985)), the CCE line (Robertson et al., *Nature* 323: 445-448 (1986)), the AK-7 line (Zhuang et al., *Cell* 77: 875-884 (1994) which is incorporated by reference herein). The success of generating a mouse line from ES cells bearing a specific targeted mutation depends on the pluripotency of the ES cells (i. e., their ability, once injected into a host developing embryo, such as a blastocyst or morula, to participate in embryogenesis and contribute to the germ cells of the resulting animal). The blastocysts containing the injected ES cells are allowed to develop in the uteri of pseudopregnant non-human females and are born as chimeric mice. The resultant transgenic mice are chimeric for cells having either the recombinase or reporter loci and are backcrossed and screened for the presence of the correctly targeted transgene(s) by PCR or Southern blot analysis on tail biopsy DNA of offspring so as to identify transgenic mice heterozygous for either the recombinase or reporter locus/loci.

Methods for producing transgenic flies, such as *Drosophila melanogaster* are also described in the art, see for example US-A-4,670,388, Brand & Perrimon, *Development* (1993) 118: 401-415; and Phelps & Brand, *Methods* (April 1998) 14: 367-379.

Transgenic worms such as *C. elegans* can be generated as described in Mello, et al., (1991) *Efficient gene transfer in C.elegans: extrachromosomal maintenance and integration of transforming sequences*. *Embo J* 10, 3959-70, Plasterk, (1995) *Reverse genetics: from gene sequence to mutant worm*. *Methods Cell Biol* 48, 59-80.

The invention also relates to transgenic non-human animals such as transgenic mouse, rats, hamsters, dogs, monkeys, rabbits, pigs, *C. elegans* and fish such as Torpedo fish comprising a nucleic acid according to the invention.

- 5 Also provided is an antibody or aptamer, or fragment or derivative thereof binding specifically to the protein encoded by said nucleic acid as is an antisense nucleic acid, an siRNA, or a ribozyme binding specifically said nucleic acid.

The Figures show:

Figure 1: Tissue distribution of NOX3 mRNA. A) NOX3 mRNA expression was evaluated in 12 rat tissues by RT-PCR (upper panel); GAPDH mRNA was used as a reference transcript (lower panel). "No cDNA" represents negative control PCR devoid of added cDNA. The first lane of both panels shows DNA size markers. B) Quantification of NOX3 RNA in 14 mouse tissues using real time PCR. NOX3 mRNA expression is shown relative to 18S rRNA expression. The amounts of NOX3 and 18S PCR products were measured using SYBR Green.

Figure 2: PCR detection of cDNAs encoding NOX activator and regulator subunits in the inner ear. A, RT-PCR amplification of NOXA1, NOXO1, and the reference GAPDH cDNA from the indicated rat tissues. B, RT-PCR amplification of p67^{phox} and p47^{phox} cDNA from the indicated rat tissues. The first lane of each panel shows DNA size markers.

Figure 3: Expression of NOX3 mRNA in specific regions of cochlea. The indicated regions of the rat inner ear were obtained by microdissection and NOX3 (upper panel) and GAPDH (lower panel) expression were assessed by RT-PCR. "+" symbols represent reverse transcribed (RT positive) samples; "-" symbols represent not reverse transcribed (RT negative) samples. P0, P3, and P4 indicate the postnatal days when samples were taken. Positive control inner ear sample was isolated from adult rat.

Figure 4: Localization of NOX3 mRNA in inner ear by *in situ* hybridization. Mouse inner ear sections hybridized with digoxigenin-labeled antisense (A, C, and E) and sense (B, D, and F) probes of NOX3, shown at ×20 (A, B) and ×40 (C-F) magnifications. A, The antisense probe hybridized with the RNA of spiral ganglion neurons. B, The sense probe yielded only a weak, uniform signal and no labeling of spiral ganglion neurons. C, Hybridization of antisense NOX3 probe with the organ of Corti labeled the sensory epithelium. D, Hybridization of sense NOX3 probe with organ of Corti did not yield specific signals. E, Antisense NOX3 probe hybridized with the sensory epithelial cell layer of the saccule. F, Only a weak uniform signal was observed with the sense NOX3 probe.

Figure 5: NOX3-dependent superoxide production in the absence of other NOX subunits. HEK293 cells were transfected with either pcDNA3.1 vector or NOX3, and superoxide generation was measured as cytochrome C reduction (upper panel) or as luminol-amplified chemiluminescence (lower panel) in the presence or absence of 100nM PMA, as indicated. Upper panel shows the result of a single experiment representative of three independent studies. Lower panel shows statistical analysis of peak superoxide production. Chemiluminescence signals were measured with relative light units (*RLU*) and normalized to 1 second and 150,000 cells.

Figure 6: Subunit regulation of NOX3 activity. A, B, and C, HEK293 cells were transfected with different combinations of NOX3, NOXO1, NOXA1, p47^{phox}, and p67^{phox}, as indicated. Superoxide generation was measured as SOD sensitive cytochrome C reduction (lines and symbols) or as luminol-amplified chemiluminescence (bar graphs) in the presence or absence of PMA (100nM), as indicated. Lines and symbols show typical experiments, representative of at least three independent studies. Bar graphs show statistical analysis of peak superoxide production. Chemiluminescence signals were measured with relative light units (*RLU*) and normalized to 1 second and 150,000 cells.

Figure 7: Cisplatin enhances NOX3-dependent superoxide production. Superoxide production of transfected HEK293 cells were measured either as luminol-amplified chemiluminescence (B, D, E and F) or with a luminol-based superoxide detection kit, Diogenes (A and C). Cells were pre-incubated in the presence or absence of 20μM cisplatin for 12 hours (A-E). A, HEK293 cells were transfected with NOX3 or control vector (pcDNA3.1) and incubated with or without cisplatin before superoxide measurement. 100nM PMA and 5μM DPI were added as indicated. Traces represent a typical experiment, representative of three independent studies. B, HEK293 cells stably expressing NOX3/NOXA1/NOXO1 were pre-incubated with or without cisplatin before superoxide measurement. 5μM DPI was added as indicated. Traces show a typical experiment, representative of eight independent studies. C, Statistical analysis of peak superoxide production of NOX3 transfected HEK293 cells, after cisplatin- or control treatment, in the presence or absence of 100nM PMA. D, Statistical analysis of peak superoxide production of HEK293 cells transfected with

the indicated constructs and pre-incubated with or without cisplatin. The measurements were carried out in the absence or presence of 100nM PMA, as indicated. *E*, Superoxide production of a HEK293 cell clone stably transfected with NOX3/NOXO1/NOXA1 after incubation with various concentrations of cisplatin for 12 hours. *F*, Superoxide production of a HEK293 cell clone stably transfected with NOX3/NOXO1/NOXA1 after incubation in the presence or absence of 20μM cisplatin for the indicated periods of time.

The following examples illustrate the invention but should not be construed as being limiting.

5 Example 1

Cloning of mouse and rat NOX3 cDNA

Experimental procedures. The first and the last exons of mouse and rat NOX3 genes
10 were identified based on their homology with the human NOX3 gene using the
Ensembl Genome Browser (www.ensembl.org). Inner ear samples of mouse (strain
C57Bl6) and rat (strain Sprague-Dawley) were isolated and total RNA was purified as
described [28]. Primers were designed and used to amplify the full length of coding
15 sequences (mouse NOX3 forward 5' – atg ccg gtg tgc tgg att ctg aac - 3' and reverse
5'- cta gaa gtt ttc ctt gtt gta ata gaa - 3', rat NOX3 forward 5'- gtg ttg gta gta aga gaa
gtg tca tg - 3' and reverse 5'- c tag aag ttg tcc ttg ttg taa tag - 3') with Taq DNA
polymerase (Qiagen) under standard conditions. PCR products were subcloned into
pcDNA3.1 vector (Invitrogen) and verified by sequencing.

20 *Results.* So far, NOX3 mRNA has only been detected in human embryonic kidney,
but expression levels were very low [22, 30] and hence the physiological relevance
questionable. We reasoned that the physiologically relevant localization of NOX3
might have been missed because previous studies had restricted their analysis to
commercially available human RNA sources. To overcome these limitations, we
25 decided to work in mouse and rat and to prepare RNA from tissues that had not been
investigated so far. As hitherto only the human NOX3 sequence was known, we
identified mouse and rat NOX3 genes by searching genomic DNA databases and
designed – based on these results – mouse and rat NOX3 PCR primers.

We then prepared RNA from a variety of mouse and rat tissues, including bone
30 (femur, skull, shoulder blade), cartilage (joints of ribs, outer ear), and inner ear and
analyzed them for NOX3 expression by RT-PCR. As shown on Fig. 1A, high levels of
NOX3 transcript were detected only in the rat inner ear sample (despite its relatively
low mRNA content demonstrated by the low amount of GAPDH PCR product). Using
primer pairs designed from the first and the last exons of the mouse and rat NOX3

gene, respectively, we amplified whole length mouse and rat NOX3 coding sequences from inner ear samples. The predicted amino acid sequences of both mouse and rat NOX3 showed 81% sequence identity with the human sequence and 93.5% identity with each other.

5

Example 2

Tissue distribution of NOX3

10

Experimental procedures. Total RNA was isolated from different organs of rat and mouse and from specific regions of the rat inner ear using the TRIzol reagent. With the exception of RNA purified from parts of the inner ear, samples were DNase treated, then further purified with RNeasy kit (Qiagen). 2 µg total RNA from each tissue was reverse transcribed using Superscript reverse transcriptase (Life Technologies, Inc.). PCR was carried out with Taq DNA polymerase using the following primers: mouse NOX3 forward 5'- gtg ata aca ggc tta aag cag aag gc -3', reverse 5'- cca ctt tcc cct act tga ctt tag -3'; rat NOX3 forward 5'- gcg tgt gct gta gag gac cgt gga g -3', reverse 5'- gag cct gtc cct ctg ctc caa atg c -3'; mouse GAPDH forward 5'- ggg tgt gaa cca cga gaa at -3', reverse 5'- gtc atg agc cct tcc aca at -3'; rat GAPDH forward 5'- cgg tgt caa cgg att tgg ccg tat t -3', reverse 5'- act gtg gtc atg agc cct tcc acg a -3'; rat NOXO1 forward 5'- acc caa acc tct gga tct gga gcc c -3', reverse 5'- gga tgg cac tca tac agg ggc gag t -3'; rat NOXA1 forward 5'- tac tgg ccg tag cac gcg aag act g -3', reverse 5'- gga cct ccc agg ctt gca gtt tga a -3'; rat p47^{phox} forward 5'- gca gga cct gtc gga gaa ggt ggt c -3', reverse 5'- tct gtc gct ggg cct ggg tta tct c -3'; rat p67^{phox} forward 5'- aag cag aag agc agt tag cat tgg c -3', reverse 5'- gga gtg cct tcc aaa ttc ttg gct g -3'. Standard PCR conditions were used, and the number of PCR cycles was 30 (Fig. 1 and 2) or 28 (Fig. 3) for the amplification of GAPDH and 35 for all other amplifications.

Quantitative PCR was carried out using ABI Prism 7900HT Sequence Detection System with standard temperature protocol and 2 x SYBR Green PCR Master Mix reagent (Applied Biosystems, Warrington, UK) in 25 µl volume, in triplicates. 300 nM of the following primer pairs were used for the reactions: mouse 18S forward 5'- aca tcc aag gaa ggc agc ag -3' and reverse 5'- ttt tcg tca cta cct ccc cg -3'; mouse NOX3

forward 5'- cga cga att caa gca gat tgc -3', and reverse 5'- aag agt ctt tga cat ggc ttt gg -3'. All amplifications were carried out in a MicroAmp optical 96-well reaction plate with optical adhesive covers (PE Applied Biosystems). The accumulation of PCR products was detected by monitoring the increase in fluorescence of the reporter dye.

Results.

NOX3 is predominantly expressed in the inner ear – Based on the cDNA sequence of mouse NOX3, we designed primers for real time PCR to study quantitative expression of NOX3 RNA in different mouse tissues. 18S RNA was used as a reference gene. The results of real-time PCR demonstrated that NOX3 was predominantly expressed in the inner ear (Fig. 1B). Low amounts of NOX3 RNA could also be detected in skull, brain, and embryonic kidney. However, inner ear contained 50-fold of the NOX3 content of skull and 870-fold of the one of embryonic kidney (Fig. 1B).

Expression of cytoplasmic NOX subunits in the inner ear – NOX1 and gp91^{phox}/NOX2 require cytoplasmic organizer subunits (NOXO1, p47^{phox}) and activator subunits (NOXA1, p67^{phox}) to form a functional enzyme. As NOX3 shows a high degree of homology with NOX1 and gp91^{phox}/NOX2 [31], we considered that it might also be a subunit-dependent enzyme and therefore investigated expression of cytoplasmic NOX subunits in the inner ear. RT-PCR analysis (using 35 PCR cycles) showed that mRNA of the activator subunit NOXA1, as well as mRNA of the organizer subunit p47^{phox} was expressed in the inner ear (Fig. 2). mRNA of the activator subunit, p67^{phox}, and the organizer subunit, NOXO1, could be detected only at very high cycle numbers (40 PCR cycles; data not shown). Since p47^{phox} mRNA is expressed in phagocytic cells, its detection might be due to blood cell contamination. In contrast, NOXA1 is not expressed in blood cells [24] nor in tissues neighboring the inner ear (Fig. 2A); thus, it is most likely expressed within cells of the inner ear.

Expression of NOX3 in different parts of the cochlea – In order to identify regions of the inner ear that express NOX3, we isolated distinct parts of rat cochlea such as organ of Corti, stria vascularis, and spiral ganglia from newborn rats (postnatal day 1 to 4) as described previously [32]. As a control tissue, we used dorsal root ganglia.

Total RNA was extracted from these tissues and tested for NOX3 and GAPDH housekeeping gene expression by RT-PCR. Results showed that NOX3 is expressed in spiral ganglia and in the organ of Corti, while stria vascularis and dorsal root ganglia were devoid of NOX3 mRNA (Fig. 3). Our experiments demonstrated that i) NOX3 is expressed only in selected structures of the cochlea (i.e. organ of Corti and spiral ganglia), and ii) its expression is not a general property of the peripheral nervous system (i.e. it was absent from dorsal root ganglia).

10 Example 3

In situ hybridization

Experimental procedures. For *in situ* hybridization experiments digoxigenin-labelled antisense and sense (negative control) cRNA probes (nucleotides 560-849 of mNOX3) were generated and used as described previously [19] on decalcified, 7µm thick inner ear sections.

Results. To further define the site of NOX3 expression, we performed *in situ* hybridization of adult mouse inner ear sections. The antisense NOX3 probe labeled spiral ganglion neurons (Fig. 4A) and cells of the organ of Corti (Fig. 4C). The cellular structures within the organ of Corti were not sufficiently well preserved to identify NOX3-expressing cells more precisely. The sense probe gave only a weak, uniform background signal demonstrating the specificity of the antisense hybridization (Fig. 4 B and D). Specific labeling for NOX3 was also observed in the vestibular system, namely in the sensory epithelial cell layer of the saccule (Fig. 4 E, F).

25 Example 4

Measurement of reactive oxygen species

Experimental procedures.

30 *Cell culture and transfection* – HEK293 were maintained in Dulbecco's Modified Eagle's Medium/Ham's Nutrient Mixture F12 that was supplemented with 10% fetal

calf serum, penicillin (100 units/ml), streptomycin (100 µg/ml), and 4 mmol/liter L-glutamine. NOX3-, NOXO1-, NOXA1-, p47^{phox}-, and p67^{phox} cDNAs were subcloned into pcDNA3.1 (Invitrogen, Groningen, Netherlands) and transfected into HEK293 cells with the Effectene transfection system (Qiagen). To obtain stable clones, NOX3,
5 NOXO1, NOXA1-transfected HEK293 cells were selected with 400 µg/ml G418 starting on the 2nd day after the transfection. After 14 days of selection, 24 surviving clones were tested for superoxide production. The positive clones were verified to express NOX3-, NOXO1-, and NOXA1 RNA by RT-PCR.

ROS generation was measured by the peroxidase-dependent luminol-amplified
10 chemiluminescence technique (referred to as luminol-amplified chemiluminescence) in 96 well microplates using Luminometer Wallac 1420 Multilabel Counter (PerkinElmer Life Sciences). Measurements were performed in Hanks' balanced salt solution supplemented with 1 mg/ml D-glucose, 1 unit/ml horseradish peroxidase, and 250 µM luminol. In some experiments, phorbol ester (PMA) was added during
15 the measurements to 100 nM final concentration. When the effect of cisplatin or 5-Fluorouracil (5-FU) was investigated, these compounds were pre-incubated with the cells for the indicated time and concentration in cell culture medium. Before ROS measurements, the cell culture medium was exchanged with the assay solution and chemiluminescence or absorption (see below) was measured at 37 °C. After
20 measurements cells were counted, and the results were normalized to 150,000 cells. Extracellular superoxide production was measured in 96-well microplates at 550 nm as the SOD-sensitive reduction of 100µM ferricytochrome C (referred to as cytochrome C reduction technique). The O₂⁻ production was calculated using an absorption coefficient of 21.1 mM⁻¹ cm⁻¹ and normalized to 10⁷ cells [29].

Results.

NOX3-dependent superoxide generation in the absence of subunits – To investigate its molecular function, we transiently expressed NOX3 in HEK293 cells, which do not
30 show endogenous expression of the enzyme. Superoxide production was measured with cytochrome C reduction technique and with luminol-amplified chemiluminescence. Using either technique, NOX3-transfected cells generated low amounts of superoxide, but only in the presence of a protein kinase C activator (phorbol ester, PMA) (Fig. 5). Since both NOX1 and gp91^{phox}/NOX2 have an

obligatory subunit requirement, the stimulus-dependent and subunit-independent activity of NOX3 is a unique and distinguishing feature of this NOX isoform.

Regulation of NOX3 by the organizer and activator subunits of NOX1 and

5 *gp91^{phox}/NOX2* – Since expression of NOX regulator and activator subunits was detected in the inner ear (see above, Fig. 2), we reasoned that they might influence NOX3 activity. Thus, we investigated superoxide generation by NOX3 upon co-transfection with cytoplasmic subunits. In the first series of experiments, NOX3 was co-transfected with the cytosolic subunits of the phagocyte NADPH oxidase, p67^{phox} and p47^{phox}. In these transfectants, the NOX3-dependent superoxide generation was markedly increased, even without an added stimulus (Fig. 6A). The addition of PMA, however, led to a strong enhancement of NOX3 activity (Fig 6A). HEK293 cells, transfected with p47^{phox} and p67^{phox} but devoid of NOX3, did not produce any superoxide (not shown). Interestingly p67^{phox} alone, in the absence of p47^{phox}, was sufficient to double the PMA-induced superoxide generation of NOX3, while p47^{phox}, in the absence of p67^{phox}, did not modify NOX3 activity (compare Fig. 5 with Fig 6A). Next it was investigated whether NOX3 could be regulated by the NOXO1 and NOXA1 subunits, which are associated with NOX1 in the colon. Co-transfection of NOX3 with NOXO1 and NOXA1 resulted in a massive increase of superoxide production (Fig. 6B). The NOXO1/NOXA1-enhanced superoxide generation was insensitive to PMA (Fig. 6B). The co-expression of NOXA1 with NOX3, in the absence of NOXO1, had an enhancing effect on PMA-stimulated NOX3 activity. NOXO1 alone, however, did not influence NOX3-dependent superoxide production (Fig. 6B, lower panel).

25 At a least on a biochemical level, there is promiscuity among the organizer and regulator subunits: NOXO1 is able to function with p67^{phox}, and NOXA1 with p47^{phox} [24-26]. Therefore, we investigated which combinations of organizer and activator subunits are capable to regulate NOX3, and what kind of properties those complexes may have. Expression of NOXO1, p67^{phox}, and NOX3 in HEK293 cells, led to spontaneous superoxide generation that could not be further enhanced by PMA (Fig. 6C). However, when p47^{phox}, NOXA1, and NOX3 were expressed, superoxide production by HEK293 cells was largely PMA-dependent (Fig. 6C). Thus, the organizer subunit (p47^{phox} versus NOXO1) determines whether NOX3 activity is PKC-dependent or independent.

30

Cisplatin enhances NOX3 activity – Cisplatin is an ototoxic drug that exerts its toxic effect, at least in part, through induction of ROS generation in the inner ear [2]. We therefore investigated the effect of this drug on NOX3 activity. HEK293 cells were transfected with NOX3 or with a control vector (pcDNA3.1) and incubated for 12 hours in the presence or absence of 20µM cisplatin. Cisplatin alone elicited superoxide production in NOX3-transfected, but not in control-transfected cells (Fig. 7A, see traces before PMA addition and Fig. 7C). Addition of PMA further increased superoxide generation, while an NADPH oxidase inhibitor, diphenylene iodonium (DPI), blocked it completely (Fig. 7A).

When HEK293 cells were co-transfected with NOX3, NOXO1 and NOXA1, they produced ROS in a constitutive manner (see Fig. 6B). To investigate the effect of cisplatin under these conditions, we generated HEK293 clones stably expressing NOX3, NOXO1, and NOXA1 subunits. These clones produced superoxide constitutively and spontaneously as observed in the transient transfectants. Upon incubation with 20µM cisplatin (12 hours), a marked increase of superoxide production was detected by the luminol-amplified chemiluminescence (Fig. 7B and C), and also by cytochrome C reduction (not shown). The superoxide generation was insensitive to PMA and could be abolished by DPI (Fig. 7B and D). As control we investigated the effect of another chemotherapeutic drugs 5-fluorouracil, , which is devoid of ototoxicity; incubation of NOX3/NOXO1/NOXA1 expressing cells with this compound (100µM, 17 hours) did not influence superoxide production (data not shown). HEK293 cells were also co-transfected with NOX3, p47^{phox}, and p67^{phox}, and incubated with 20 µM cisplatin for 12 hours. Cisplatin enhanced the superoxide production of NOX3-, p47^{phox}-, and p67^{phox}-transfected cells by a factor of approximately 3.3 (Fig. 7D); this superoxide production could be blocked by addition of 5µM DPI (not shown).

Next the concentration and time dependency of the cisplatin effect on NOX3 activity was investigated using a NOX3/NOXO1/NOXA1 transfected stable clone. After incubating the cells with various concentrations of cisplatin for 12 hours, superoxide production was measured (Fig. 7E). Cisplatin caused an increase of NOX3-dependent ROS generation already at 1µM concentration, and 20µM cisplatin had a maximal effect (Fig. 7E). The EC₅₀ of NOX3 activation by cisplatin was 3.6 +/- 1.4 µM.

In order to examine the time course of NOX3 activation by cisplatin, a NOX3/NOXO1/NOXA1 transfected stable clone was incubated with 20 μ M cisplatin for various periods of time. Cisplatin enhanced NOX3 activity already after 5 hours treatment and reached its maximal effect after around 17 hours (Fig. 7F); the t_{50} was

5 11.5 \pm 1.7 hours.

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Claims

1. A method of identifying a modulator of an NADPH oxidase, whereby said modulator is suitable as a lead compound and/or as a medicament for the treatment and/or prevention of hearing loss and/or phantom hearing, the method comprising the steps of
- 5 (a) contacting a test compound with a protein, wherein said protein
- (i) comprises or consists of the amino acid sequence of any one of SEQ ID NO: 1, 3 or 5, or
- 10 (ii) is encoded by a nucleic acid comprising or consisting of the sequence of any one of SEQ ID NO: 2, 4, 6, 23 or 24, or
- (iii) is a fragment of the protein according to (i) or (ii) and exhibits NADPH oxidase activity, or
- (iv) has a sequence at least 75% identical with the protein according to (i) or (ii) or with the fragment according to (iii) and exhibits NADPH oxidase activity,
- 15 under conditions allowing binding of said test compound to said protein; and
- (b) determining whether said test compound, upon contacting in step (a) modulates the expression and/or activity of said protein.
- 20
2. A method of identifying a modulator of an NADPH oxidase, whereby said modulator is suitable as a lead compound and/or as a medicament for the treatment and/or prevention of hearing loss and/or phantom hearing, the method comprising the steps of
- 25 (a) contacting a test compound with a protein, wherein said protein
- (i) comprises or consists of the amino acid sequence of any one of SEQ ID NO: 1, 3 or 5, or
- (ii) is encoded by a nucleic acid comprising or consisting of the sequence of any one of SEQ ID NO: 2, 4, 6, 23 or 24, or
- 30 (iii) is a fragment of the protein according to (i) or (ii) and exhibits NADPH oxidase activity, or
- (iv) has a sequence at least 75% identical with the protein according to (i) or (ii) or with the fragment according to (iii) and exhibits

NADPH oxidase activity,

under conditions allowing binding of said test compound to said protein;

(b) determining whether said test compound, upon contacting in step (a) modulates the expression and/or activity of said protein; and

(c) performing clinical trials with said modulator.

3. The method of claim 1 or 2, wherein said contacting comprises contacting with one or more NADPH oxidase subunits, under conditions allowing binding of said test compounds to said subunit(s), and wherein said determining comprises determining whether said test compound modulates the expression and/or activity of said subunit(s).

4. The method of any one of claims 1 to 3, further comprising, prior to step (b), the step of

(b') determining whether said test compound binds to said protein or, if present, said subunit(s),

wherein said determining in step (b) is effected upon binding in step (b').

5. A method of identifying a modulator of an NADPH oxidase, whereby said modulator is suitable as a lead compound and/or as a medicament for the treatment and/or prevention of hearing loss and/or phantom hearing, the method comprising the steps of

(a) contacting a test compound with a protein, wherein said protein

(i) comprises or consists of the amino acid sequence of any one of SEQ ID NO: 1, 3 or 5, or

(ii) is encoded by a nucleic acid comprising or consisting of the sequence of any one of SEQ ID NO: 2, 4, 6, 23 or 24, or

(iii) is a fragment of the protein according to (i) or (ii) and exhibits NADPH oxidase activity, or

(iv) has a sequence at least 75% identical with the protein according to (i) or (ii) or with the fragment according to (iii) and exhibits NADPH oxidase activity,

and optionally with one or more NADPH oxidase subunits, under conditions allowing binding of said test compound to said protein or, if

present, said subunit(s);

- (b) optionally determining whether said test compound binds to said protein or, if present, said subunit(s); and
- (c) determining whether (ca) said test compound, upon contacting in step (a); or (cb) said test compound, upon binding in step (b) modulates the expression and/or activity of said protein or, if present, said subunit(s).

6. The method of any one of any one of claims 1 to 5, wherein modulation involves modulating the reactive oxygen species (ROS) production of said protein, and wherein determining in step (c) comprises quantifying ROS production.

7. The method of any one of claims 1 to 6, wherein said NADPH oxidase subunit(s) is/are the activating subunit(s) NOXA1 and/or p67^{phox}/NOXA2, and/or the organising subunit(s) NOXO1 and/or p47^{phox}/NOXO2.

8. The method of any of the preceding claims, wherein said protein and, if present, said subunit(s) is/are comprised in a membrane preparation.

9. The method of any of the preceding claims, wherein said protein and, if present, said subunit(s) is/are comprised in a cell transfected with a nucleic acid encoding said protein.

10. The method of any of the preceding claims, wherein said protein and, if present, said subunit(s) is/are comprised in a non-human animal.

11. The method of claim 10, wherein the modulation of ROS production involves improving the hearing of said animal and determining in step (c) involves quantifying said hearing.

12. The method of any of the preceding claims, wherein, prior to said contacting, (a') an ototoxic agent and/or an agent increasing the activity and/or the expression of said protein or subunit(s), is brought into contact with said protein or subunit(s) is/are administered to said cell or said animal.

13. The method of claim 12, wherein said ototoxic agent is selected from the group consisting of salicylates, non-steroidal antiinflammatories, antibiotics, diuretics, cytostatics, quinine and gastroprotective drugs.

14. The method of any of the preceding claims, wherein said NADPH oxidase is NOX3.

15. The method of any of the preceding claims, wherein said NADPH oxidase is the protein defined in claim 1.

16. The method of any of the preceding claims, wherein the method further comprises the step of formulating said modulator with a pharmaceutically acceptable carrier.

17. The method of claim 16, wherein, prior to said formulating, the affinity, specificity and/or pharmacological properties of the modulator are optimized.

18. A pharmaceutical composition comprising

(a) an antibody, aptamer, or a fragment or derivative thereof binding specifically the protein defined in claim 1;

(b) an antisense nucleic acid, an siRNA, or a ribozyme binding specifically a nucleic acid encoding said protein;

(c) a compound comprising the fragment of SEQ ID NO: 11 from position 202 to position 212, the fragment of SEQ ID NO: 11 from position 402 to position 463, the fragment of SEQ ID NO: 15 from position 200 to position 210, the fragment of SEQ ID NO: 15 from position 457 to position 513, the fragment of SEQ ID NO: 7 from position 158 to position 217, the fragment of SEQ ID NO: 7 from position 233 to position 289, the fragment of SEQ ID NO: 7 from position 321 to position 331, the fragment of SEQ ID NO: 19 from position 156 to position 216, the fragment of SEQ ID NO: 19 from position 226 to position 286, the fragment of SEQ ID NO: 19 from position 360 to position 370, wherein said compound may furthermore comprise a cell-

penetrating peptide;

(d) a nucleic acid comprising a sequence encoding any of the fragments according to (c), wherein said nucleic acid may optionally comprise a sequence encoding a cell-penetrating peptide;

(e) arylodonium compounds such as diphenylene iodonium (DPI), di-2-thienyliodonium, phenoxaiodonium;

(f) naphthoquinones such as plumbagin, acetylshikonin;

(g) inhibitors of HMG-CoA reductase including statins such as lovastatin, simvastatin, atorvastatin;

(h) gliotoxin;

(i) phenothiazines such as phenothiazine, trifluoperazine, and/or

(j) a derivative of any one of (e) to (i).

19. A pharmaceutical composition consisting of

(a) ortho-methoxy-substituted catechols such as apocynin, acetosyringone, vanillin, vanillic acid, syringaldehyde, syringic acid; and

(b) a pharmaceutically acceptable carrier, excipient or diluent.

20. A pharmaceutical composition comprising

(a) an ototoxic agent; and

(b) a compound selected from the group consisting of:

(i) an antibody, aptamer, or a fragment or derivative thereof binding specifically the protein defined in claim 1;

(ii) an antisense nucleic acid, an siRNA, or a ribozyme binding specifically a nucleic acid encoding said protein;

(iii) a compound comprising the fragment of SEQ ID NO: 11 from position 202 to position 212, the fragment of SEQ ID NO: 11 from position 402 to position 463, the fragment of SEQ ID NO: 15 from position 200 to position 210, the fragment of SEQ ID NO: 15 from position 457 to position 513, the fragment of SEQ ID NO: 7 from position 158 to position 217, the fragment of SEQ ID NO: 7 from position 233 to position 289, the fragment of SEQ ID NO: 7 from position 321 to position 331, the fragment of SEQ ID NO: 19 from

position 156 to position 216, the fragment of SEQ ID NO: 19 from position 226 to position 286, the fragment of SEQ ID NO: 19 from position 360 to position 370, wherein said compound may furthermore comprise a cell-penetrating peptide;

- (iv) a nucleic acid comprising a sequence encoding any of the fragments according to (c), wherein said nucleic acid may optionally comprise a sequence encoding a cell-penetrating peptide;
- (v) arylodonium compounds such as diphenylene iodonium (DPI), di-2-thienyliodonium, phenoxaiodonium;
- (vi) naphthoquinones such as plumbagin, acetylshikonin;
- (vii) inhibitors of HMG-CoA reductase including statins such as lovastatin, simvastatin, atorvastatin;
- (viii) gliotoxin;
- (ix) phenothiazines such as phenothiazine, trifluoperazine, and/or
- (x) a derivative of any one of (v) to (ix).

21. The pharmaceutical composition of claim 20, wherein said ototoxic agent is an antibiotic.

22. The pharmaceutical composition of claim 20 or 21, wherein said ototoxic agent is an aminoglycoside antibiotic, preferably gentamycin.

23. Use of a modulator of the protein defined in claim 1 for the preparation of a pharmaceutical composition for the treatment and/or prevention of hearing loss and/or phantom hearing, wherein said modulator is selected from the group consisting of

- (a) an antibody, aptamer, or a fragment or derivative thereof binding specifically said protein;
- (b) an antisense nucleic acid, an siRNA, or a ribozyme binding specifically a nucleic acid encoding said protein;
- (c) a known modulator of NOX3 and/or NADPH oxidases and/or electron transport proteins wherein said known modulator is selected from the group consisting of:

- (i) arylodonium compounds such as diphenylene iodonium (DPI), di-2-thienyliodonium, phenoxaiodonium;
- (ii) ortho-methoxy-substituted catechols such as apocynin, acetosyringone, vanillin, vanillic acid, syringaldehyde, syringic acid;
- (iii) naphthoquinones such as plumbagin, acetylshikonin;
- (iv) inhibitors of HMG-CoA reductase including statins such as lovastatin, simvastatin, atorvastatin;
- (v) gliotoxin;
- (vi) phenothiazines such as phenothiazine, trifluoperazine; and
- (vii) a derivative of any one of (i) to (vi).
- (d) a compound comprising the fragment of SEQ ID NO: 11 from position 202 to position 212, the fragment of SEQ ID NO: 11 from position 402 to position 463, the fragment of SEQ ID NO: 15 from position 200 to position 210, the fragment of SEQ ID NO: 15 from position 457 to position 513, the fragment of SEQ ID NO: 7 from position 158 to position 217, the fragment of SEQ ID NO: 7 from position 233 to position 289, the fragment of SEQ ID NO: 7 from position 321 to position 331, the fragment of SEQ ID NO: 19 from position 156 to position 216, the fragment of SEQ ID NO: 19 from position 226 to position 286, the fragment of SEQ ID NO: 19 from position 360 to position 370, wherein said compound may furthermore comprise a cell-penetrating peptide; and
- (e) a nucleic acid comprising a sequence encoding any of the fragments according to (d), wherein said nucleic acid may optionally comprise a sequence encoding a cell-penetrating peptide.

24. Use of a cisplatin and/or hydrogen hexachloroplatinate for the preparation of a pharmaceutical composition for the treatment and/or prevention of tinnitus.

25. A method of diagnosing hearing loss and/or phantom hearing and/or an individual's disposition or risk to develop said loss and/or said phantom hearing, comprising the steps of:

- (a) determining (a) polymorphism(s) in a NOX3 gene or cDNA and/or in a

gene or cDNA encoding an NADPH oxidase subunit in a sample obtained from said individual; and

- (b) associating said polymorphism(s) with a disease state or disposition state.

5

26. Use of a compound binding to the protein defined in claim 1 or to a subunit defined in claim 3 for the preparation of a diagnostic composition for the diagnosis of hearing loss and/or phantom hearing and/or an individual's disposition or risk to develop said loss and/or said phantom hearing, wherein said compound is selected from the group consisting of

10

- (a) an antibody, aptamer, or a fragment or derivative thereof binding specifically said protein; and
- (b) a known modulator of NOX3 and/or NADPH oxidases and/or electron transport proteins, wherein said known modulator is selected from the group consisting of:

15

- (i) arylodonium compounds such as diphenylene iodonium (DPI), di-2-thienyliodonium, phenoxaiodonium;
- (ii) ortho-methoxy-substituted catechols such as apocynin, acetosyringone, vanillin, vanillic acid, syringaldehyde, syringic acid;
- (iii) cisplatin, hydrogen hexachloroplatinate;
- (iv) naphthoquinones such as plumbagin, acetylshikonin;
- (v) inhibitors of HMG-CoA reductase including statins such as lovastatin, simvastatin, atorvastatin;
- (vi) gliotoxin;
- (vii) phenothiazines such as phenothiazine, trifluoperazine; and
- (viii) a derivative of any one of (i) to (vii).

20

25

27. Use of a compound binding to a nucleic acid encoding the protein defined in claim 1 or a subunit defined in claim 3 for the preparation of a diagnostic composition for the diagnosis of hearing loss and/or phantom hearing and/or an individual's disposition or risk to develop said loss and/or said phantom hearing, wherein said compound is a nucleic acid complementary to said nucleic acid and at least 15 nucleotides in length.

30

28. The use of claim 26 or 27, wherein said compound is detectably labelled.
29. The use of claim 28, wherein said diagnosis to be performed involves imaging
5 of the human or animal body.
30. The method of any one of claims 10 to 17 or the use of claim 29, wherein said animal is a rodent.
- 10 31. The method of claim 30, wherein said rodent is mouse or rat.
32. The method or the use of any of the preceding claims, wherein said modulator is an inhibitor.
- 15 33. A nucleic acid
- (i) comprising or consisting of the sequence of SEQ ID NO: 6, or
 - (ii) encoding a protein comprising or consisting of the sequence of SEQ ID NO: 5, or
 - (iii) encoding a fragment of the protein according to (ii), wherein said
20 fragment exhibits NADPH oxidase activity, or
 - (iv) encoding a protein having a sequence at least 95% identical with the protein according to (ii) or with the fragment according to (iii) and exhibiting NADPH oxidase activity.
- 25 34. A vector comprising the nucleic acid according to claim 33.
35. A protein encoded by the nucleic acid according to claim 33.
36. A non-human host comprising the nucleic acid according to claim 33, the
30 vector according to claim 34, and/or the protein according to claim 35.
37. The host according to claim 36, which is a cell.
38. The host according to claim 36, which is a transgenic non-human animal.

39. An antibody or aptamer, or fragment or derivative thereof binding specifically to the protein according to claim 35.
- 5 40. An antisense nucleic acid, an siRNA, or a ribozyme binding specifically the nucleic acid according to claim 33.

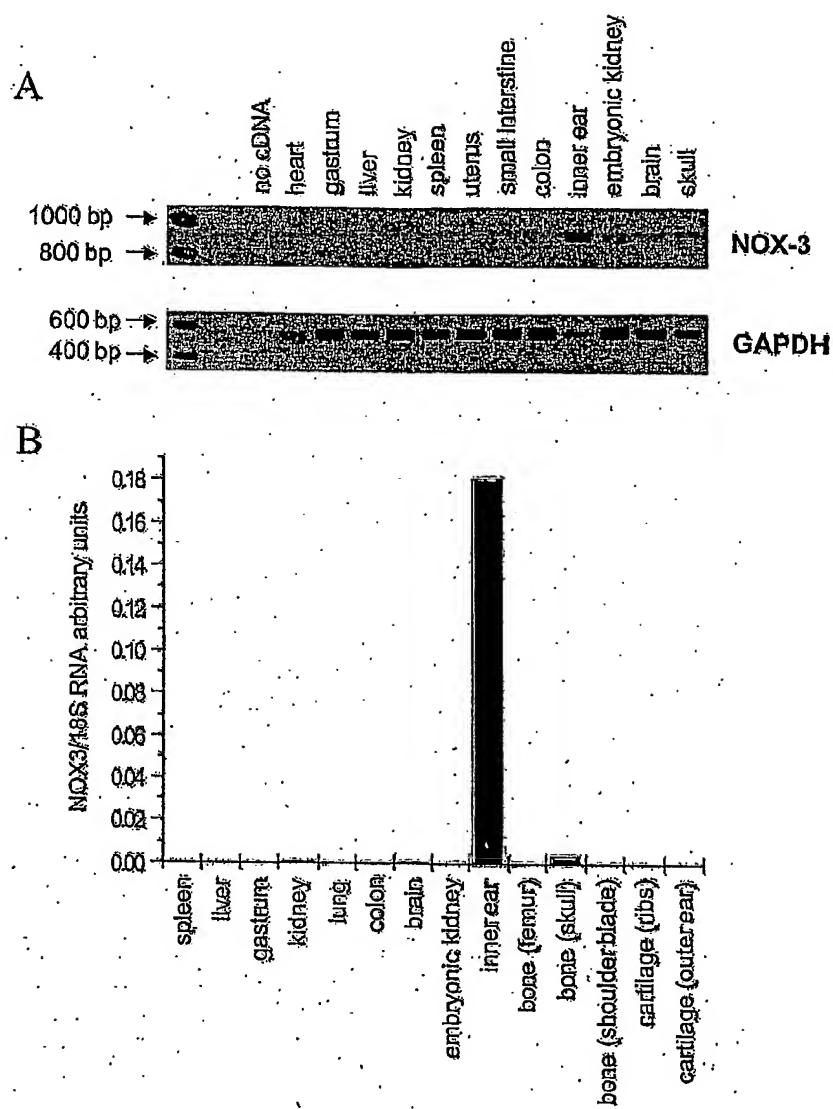


Figure 1

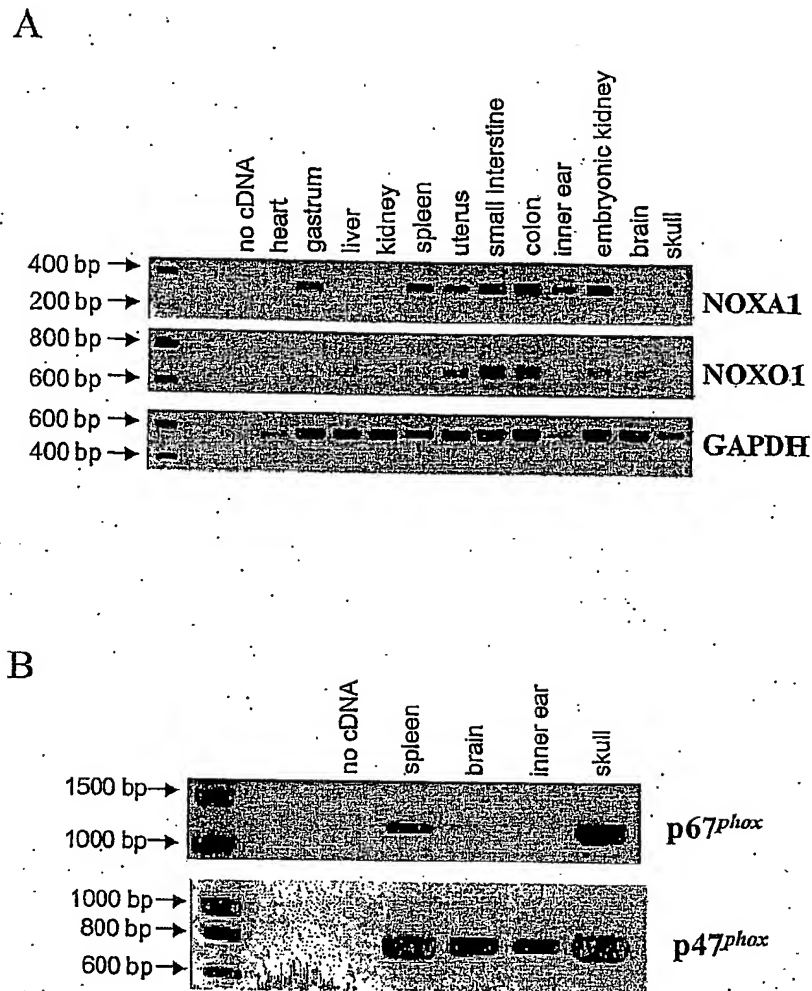


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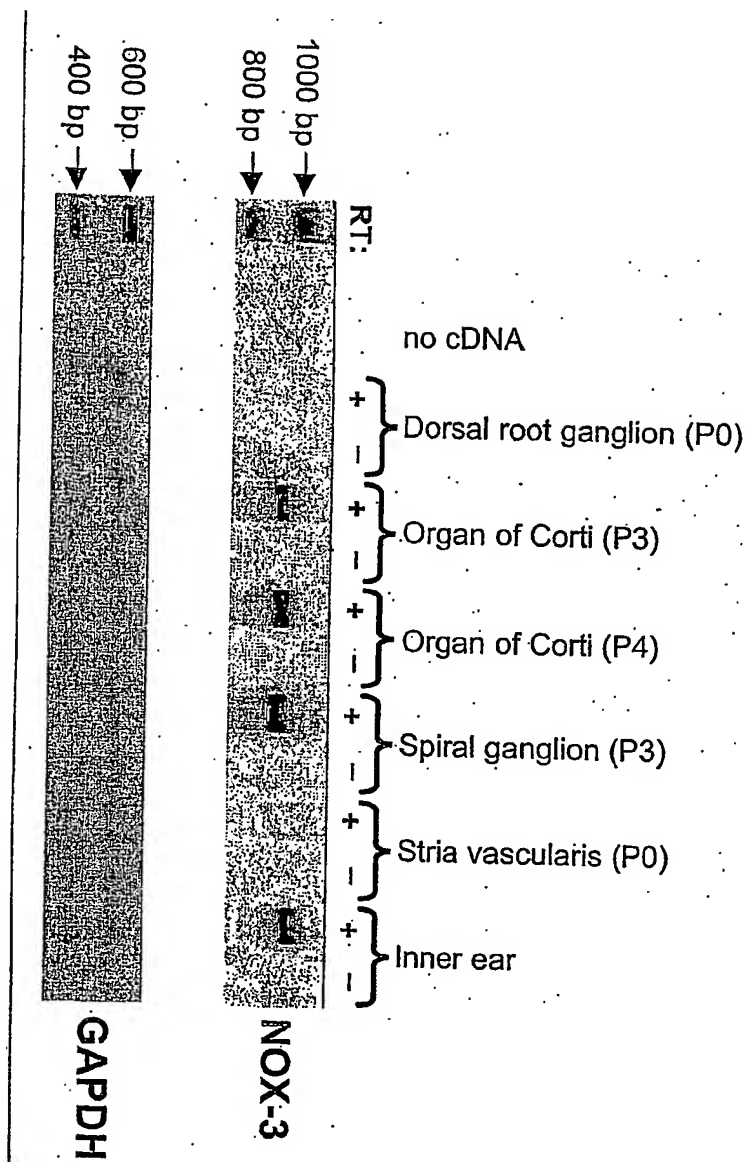


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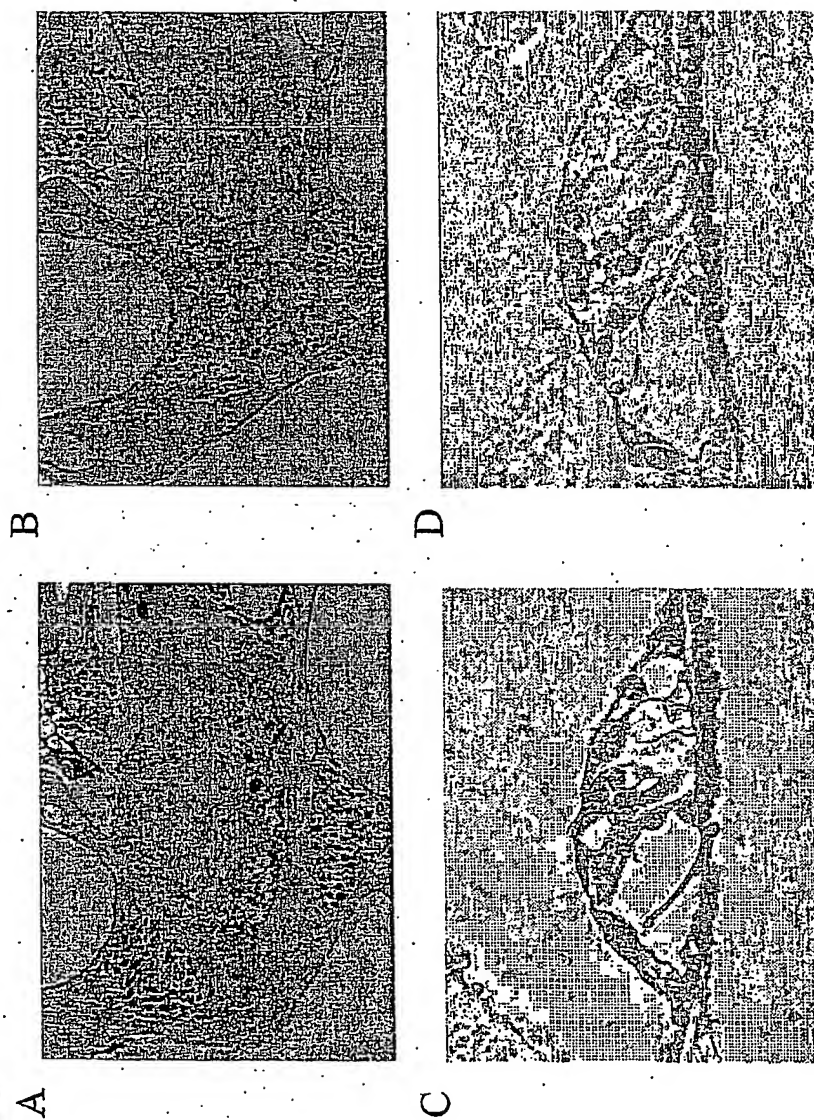


Figure 4A – D

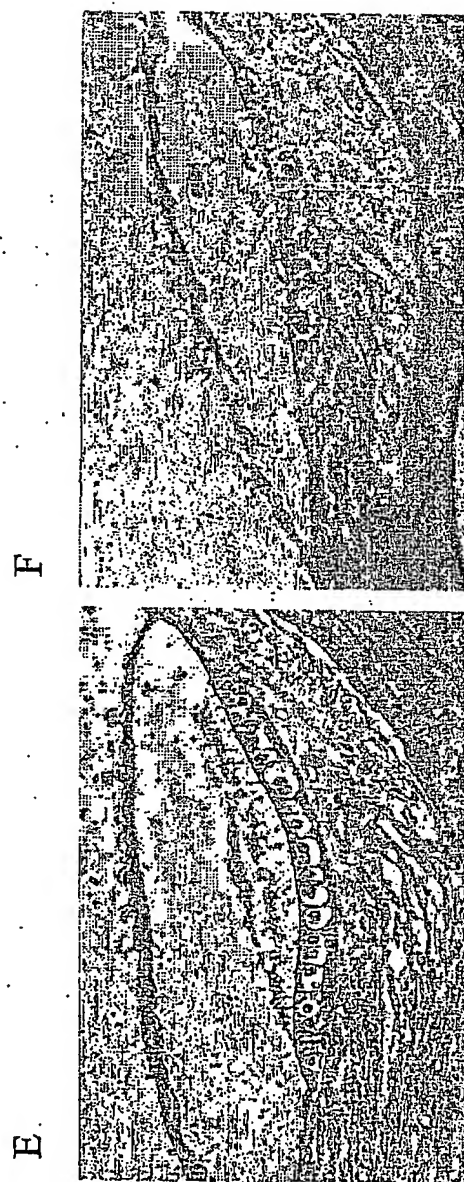


Figure 4E + F

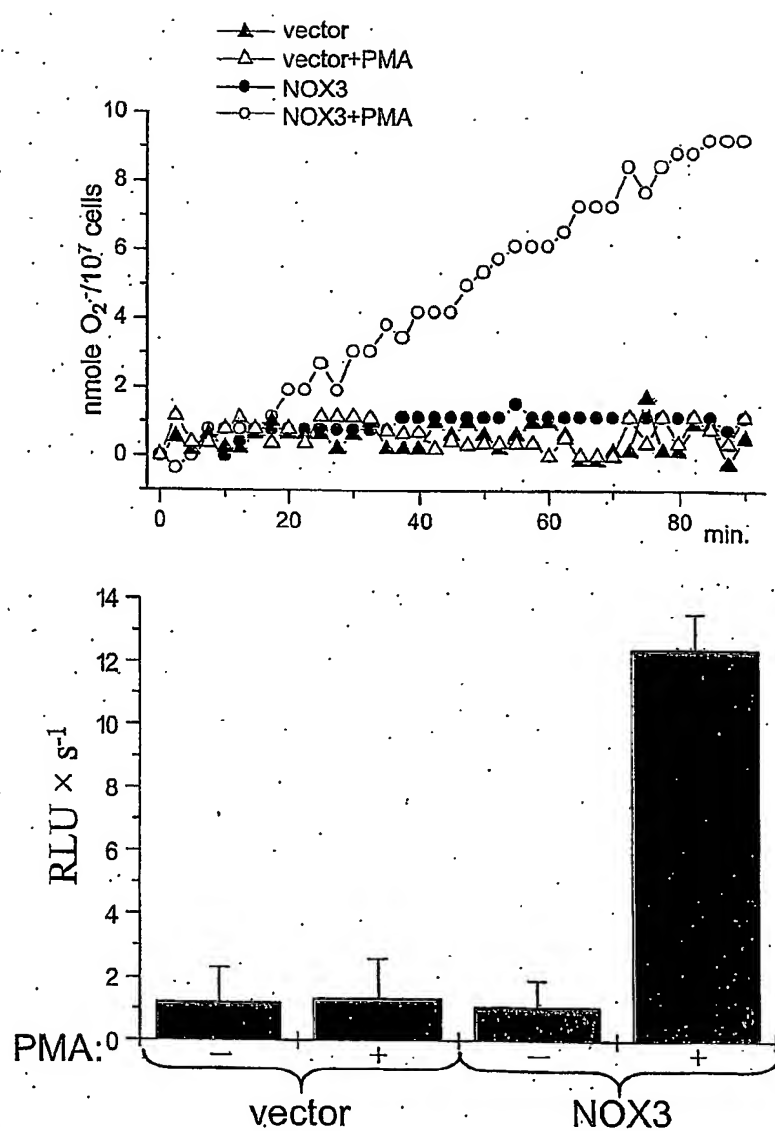


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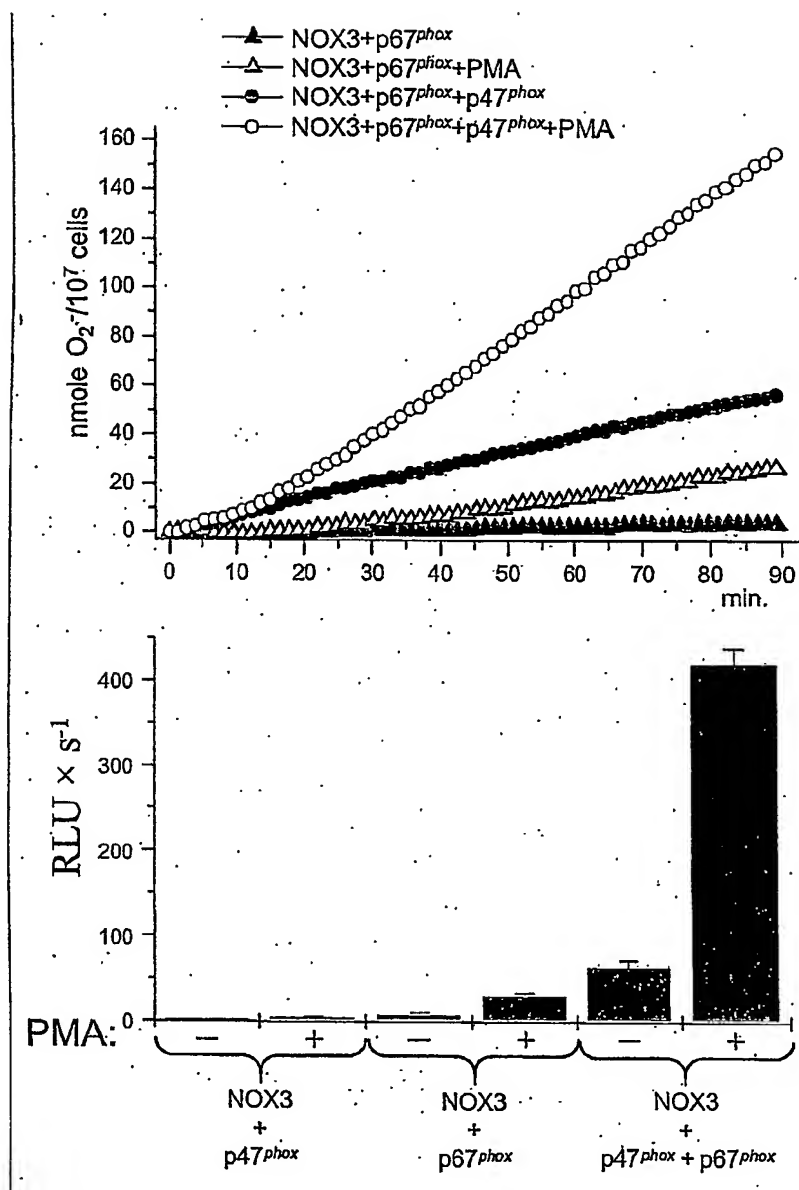


Figure 6A

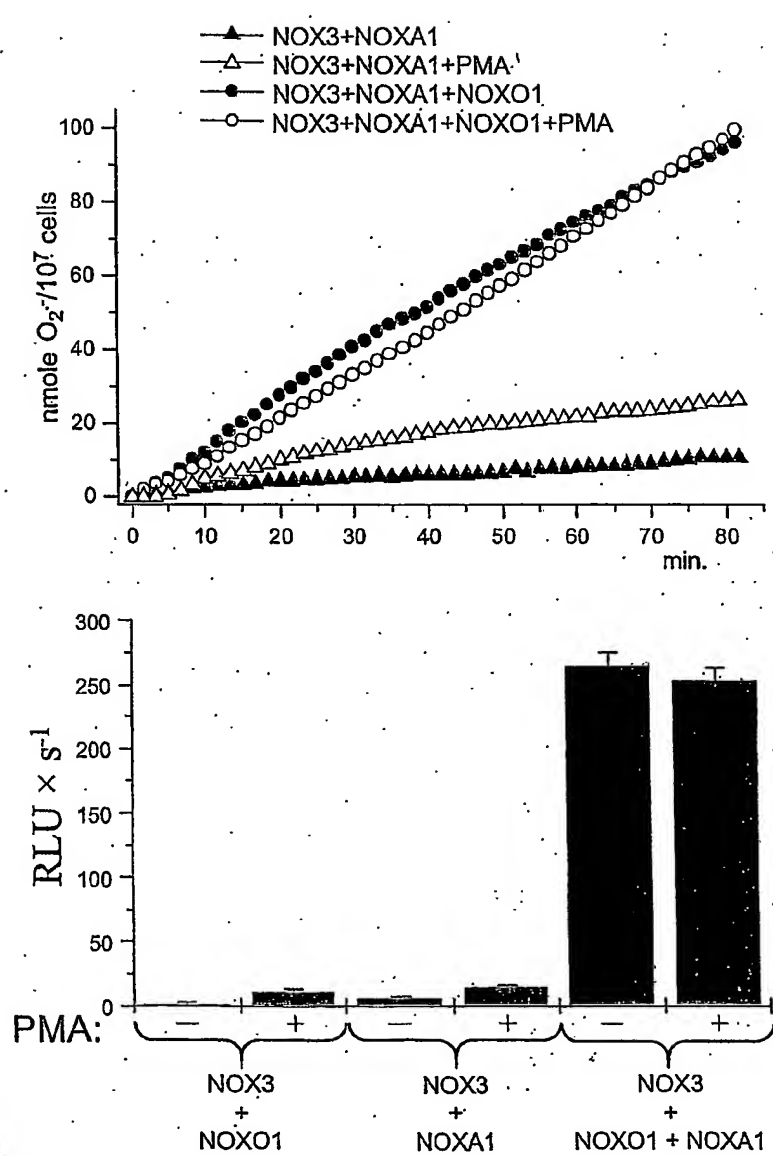


Figure 6B

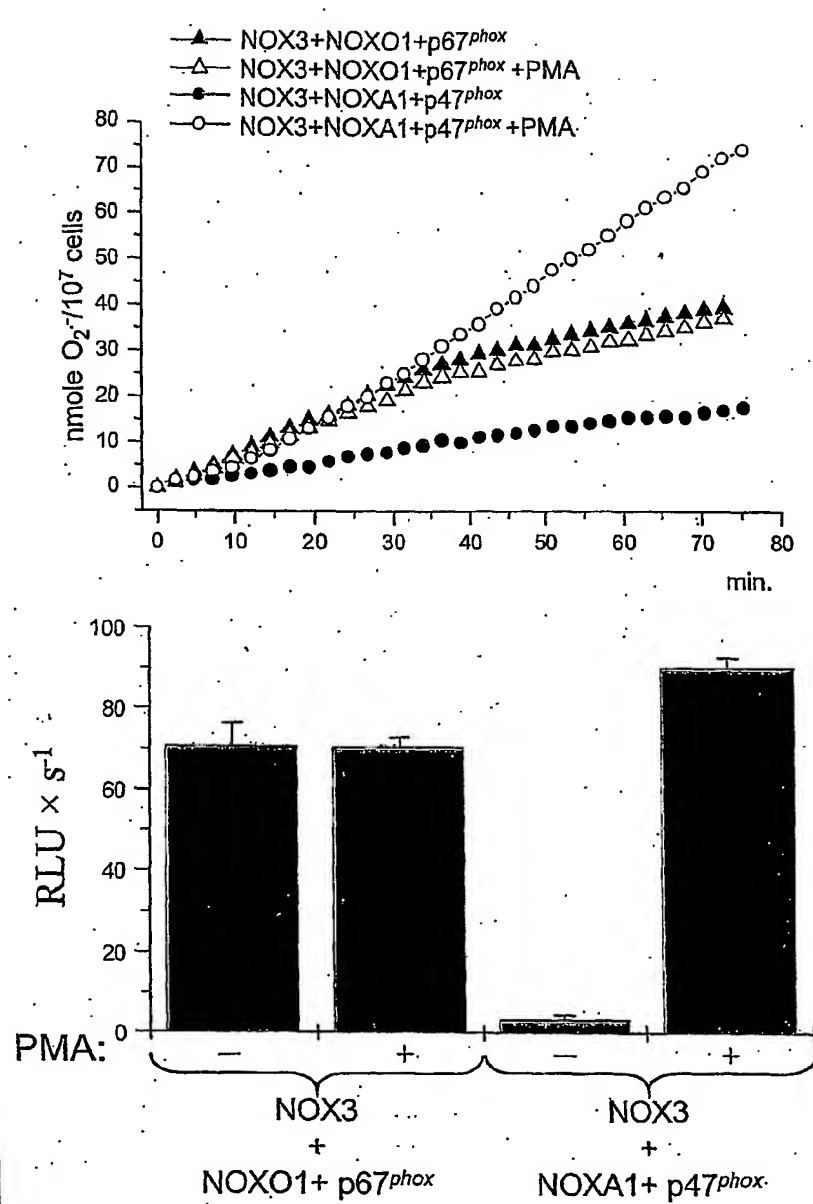


Figure 6C

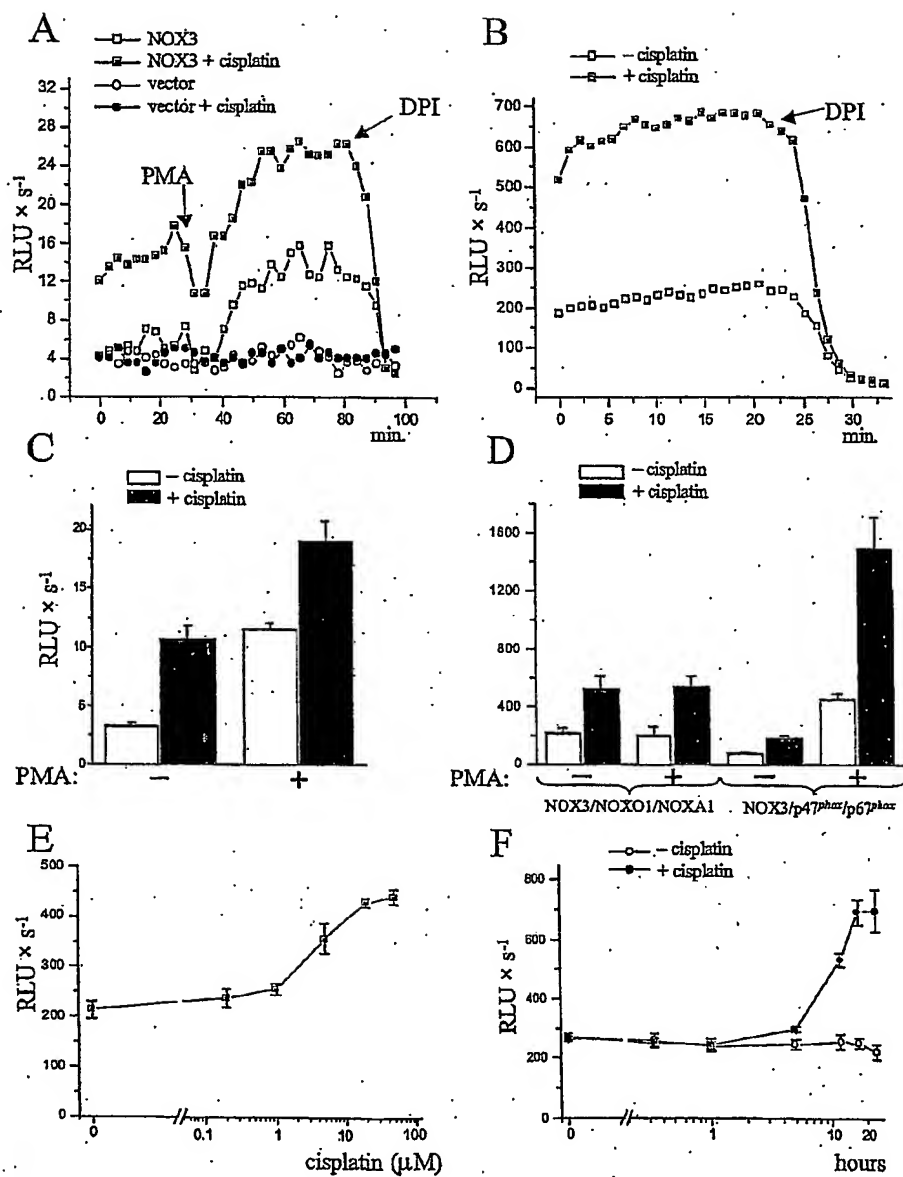


Figure 7

1
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Val 385	Asp	Gly	Pro	Phe	Gly 390	Thr	Ala	Leu	Thr	Asp 395	Val	Phe	His Tyr	Pro 400
Val	Cys	Val	Cys 405	Val	Ala	Ala	Gly	Ile	Gly 410	Val	Thr	Pro	Phe Ala	Ala 415
Leu	Leu	Lys	Ser 420	Ile	Trp	Tyr	Lys	Cys 425	Ser	Glu	Ala	Gln	Thr Pro	Leu 430
Lys	Leu	Ser 435	Lys	Val	Tyr	Phe	Tyr 440	Trp	Ile	Cys	Arg	Asp 445	Ala Arg	Ala
Phe	Glu 450	Trp	Phe	Ala	Asp	Leu 455	Leu	Leu	Ser	Leu	Glu 460	Thr	Arg Met	Ser
Glu 465	Gln	Gly	Lys	Thr	His 470	Phe	Leu	Ser	Tyr	His 475	Ile	Phe	Leu Thr	Gly 480

Trp Asp Glu Asn Gln Ala Leu His Ile Ala Leu His Trp Asp Glu Asn
 485 490 495

Thr Asp Val Ile Thr Gly Leu Lys Gln Lys Thr Phe Tyr Gly Arg Pro
 500 505 510

Asn Trp Asn Asn Glu Phe Lys Gln Ile Ala Tyr Asn His Pro Ser Ser
 515 520 525

Ser Ile Gly Val Phe Phe Cys Gly Pro Lys Ala Leu Ser Arg Thr Leu
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Gln Lys Met Cys His Leu Tyr Ser Ser Ala Asp Pro Arg Gly Val His
 545 550 555 560

Phe Tyr Tyr Asn Lys Glu Ser Phe
 565

<210> 2
 <211> 1707
 <212> DNA
 <213> Homo sapiens

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 cattacacac gagttatttt ggggtcaaca ctggcttggg cagcagcatc cgcactgtgc 180
 ctgaatttta actgcatgct aattctaata cctgtcagtc gaaaccttat ttcattcata 240
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 tttcacaac tggtcgcta tgggtagct gttaatgcaa ccatccacat cgtggcgcat 360
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 cccacaaaca caaccactga attgctaagg acaatagcag gcgtcaccgg tctggtgatc 540
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 ttctattaca acaaggagag cttctag 1707

<210> 3
 <211> 568
 <212> PRT
 <213> Mus musculus

<400> 3

Met Pro Val Cys Trp Ile Leu Asn Glu Ser Gly Ser Phe Val Val Ala
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Leu Leu Trp Leu Ala Val Asn Ala Tyr Leu Phe Ile Asp Thr Phe Phe
 20 25 30

Trp Tyr Thr Glu Glu Glu Ala Phe Phe Tyr Thr Arg Val Ile Leu Gly
 35 40 45

Ser Ala Leu Ala Trp Ala Arg Ala Ser Ala Val Cys Leu Asn Phe Asn
 50 55 60

Cys Met Leu Ile Leu Leu Pro Val Ser Arg Asn Phe Ile Ser Leu Val
 65 70 75 80

Arg Gly Thr Ser Val Cys Cys Arg Gly Pro Trp Arg Arg Gln Leu Asp
 85 90 95

Lys Asn Leu Asn Phe His Lys Leu Val Ala Tyr Gly Ile Ala Val Asn
 100 105 110

Ser Val Ile His Ile Val Ala His Leu Phe Asn Leu Glu Arg Tyr His
 115 120 125

Leu Gly Gln Ala Lys Asp Ala Glu Gly Leu Leu Ala Ala Leu Ser Lys
 130 135 140

Leu Gly Asp Ala Pro Asn Glu Ser Tyr Leu Asn Pro Val Arg Thr Phe
 145 150 155 160

Tyr Met Gly Thr Thr Thr Glu Leu Leu Met⁵ Thr Val Ser Gly Ile Thr
 165 170 175
 Gly Leu Gly Ile Ser Leu Ala Leu Val Phe Ile Met Thr Ser Ser Thr
 180 185 190
 Glu Phe Ile Arg Arg Ser Ser Tyr Glu Leu Phe Trp Tyr Thr His His
 195 200 205
 Ile Phe Val Phe Phe Phe Ile Ser Leu Ala Ile His Gly Gly Gly Arg
 210 215 220
 Ile Ile Arg Gly Gln Thr Pro Glu Ser Leu Arg Leu His Asn Val Thr
 225 230 235 240
 Tyr Cys Arg Asp His Tyr Ala Glu Trp Gln Ala Ala Ala Leu Cys Pro
 245 250 255
 Val Pro Gln Phe Ser Gly Lys Glu Pro Ser Ala Trp Lys Trp Ala Leu
 260 265 270
 Gly Pro Val Val Leu Tyr Ala Cys Glu Arg Ile Ile Arg Phe Trp Arg
 275 280 285
 Ser His Gln Glu Val Val Ile Thr Lys Val Val Ser His Pro Ser Ala
 290 295 300
 Val Leu Glu Leu His Met Lys Lys Arg Asp Phe Lys Met Ala Pro Gly
 305 310 315 320
 Gln Tyr Ile Phe Ile Gln Cys Pro Ser Val Ser Pro Leu Glu Trp His
 325 330 335
 Pro Phe Thr Leu Thr Ser Ala Pro Gln Glu Asp Phe Phe Ser Val His
 340 345 350
 Ile Arg Ala Ser Gly Asp Trp Thr Glu Ala Leu Leu Lys Ala Phe Arg
 355 360 365
 Val Glu Gly Gln Ala Pro Ser Glu Leu Cys Ser Met Pro Arg Leu Ala
 370 375 380
 Val Asp Gly Pro Phe Gly Gly Ser Leu Ala Asp Val Phe His Tyr Pro
 385 390 395 400
 Val Ser Val Cys Ile Ala Thr Gly Ile Gly Val Thr Pro Phe Ala Ser
 405 410 415
 Leu Leu Lys Ser Val Trp Tyr Lys Cys Cys Glu Ser Gln Ser Leu Pro
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<210>	4
<211>	1707
<212>	DNA
<213>	Mus musculus

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gagctcttct ggtacacaca ccatactttt gtcttcttct tcatcagtct ggccatccac	660
ggaggagggtc gcatacttcg aggccaaact ccagagagtc tccggctgca caatgtcacg	720
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tctggcaagg aaccttcggc ctggaaatgg gctttgggtc ctgtggtctt gtatgcgtgt	840

7

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ttctattaca acaaggaaaa cttctag 1707

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<210> 5
 <211> 568
 <212> PRT
 <213> Rattus norvegicus

<400> 5

Met Pro Thr Cys Trp Ile Leu Asn Glu Ser Val Ser Phe Val Val Ala
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Trp Tyr Ala Glu Glu Glu Ser Phe Phe Tyr Thr Arg Val Ile Leu Gly
 35 40 45

Ser Ala Leu Ala Trp Ala Arg Ala Ser Ala Val Cys Leu Asn Phe Asn
 50 55 60

Cys Met Leu Ile Leu Leu Pro Val Ser Arg Asn Phe Val Ser Leu Val
 65 70 75 80

Arg Gly Thr Ser Val Cys Cys Arg Gly Pro Trp Arg Arg Gln Leu Asp
 85 90 95

Lys Asn Leu Lys Phe His Lys Leu Val Ala Tyr Gly Ile Ala Val Asn
 100 105 110

Ser Val Ile His Ile Val Ala His Leu Phe Asn Leu Glu Arg Tyr His
 115 120 125

8

Leu Gly Gln Ala Lys Asp Ala Glu Gly Leu Leu Ala Ala Leu Ser Lys
 130 135 140

Leu Gly Asn Ala Pro Asn Glu Ser Tyr Leu Asn Pro Val Arg Thr Leu
 145 150 155 160

Tyr Thr Gly Thr Thr Thr Gln Leu Leu Met Thr Val Ser Gly Ile Thr
 165 170 175

Gly Leu Val Ile Ser Leu Ala Leu Ile Leu Ile Met Thr Ser Ser Thr
 180 185 190

Glu Phe Ile Arg Gln Ser Ser Tyr Glu Leu Phe Trp Tyr Thr His His
 195 200 205

Ile Phe Ile Phe Leu Phe Ile Ser Leu Ala Ile His Gly Gly Gly Arg
 210 215 220

Ile Ile Arg Gly Gln Thr Pro Glu Ser Leu Arg Leu His Asn Val Thr
 225 230 235 240

Phe Cys Arg Asp His Phe Asp Glu Trp Gln Glu Ala Ala Ser Cys Pro
 245 250 255

Val Pro Gln Phe Ser Gly Lys Glu Pro Ser Ala Trp Lys Trp Thr Leu
 260 265 270

Gly Pro Val Val Leu Tyr Ala Cys Glu Ile Ile Ile Arg Phe Trp Arg
 275 280 285

Ser His Gln Glu Val Val Ile Thr Lys Val Val Ser His Pro Ser Ala
 290 295 300

Val Leu Glu Leu His Met Lys Lys Arg Asp Phe Lys Met Ala Pro Gly
 305 310 315 320

Gln Tyr Ile Phe Ile Gln Cys Pro Ser Ile Ser Pro Leu Glu Trp His
 325 330 335

Pro Phe Thr Leu Thr Ser Ala Pro Gln Glu Asp Phe Phe Ser Val His
 340 345 350

Ile Arg Ala Ser Gly Asp Trp Thr Glu Ala Leu Leu Lys Ala Phe Gly
 355 360 365

Ala Glu Gly Gln Ala Pro Ser Glu Leu Cys Ser Met Pro Arg Leu Ala
 370 375 380

Val Asp Gly Pro Phe Gly Gly Ser Leu Ala Asp Val Phe His Tyr Pro
 385 390 395 400

Val Ser Val Cys Ile Ala Thr Gly Ile Gly Val Thr Pro Phe Ala Ser
 405 410 415

Leu Leu Lys Ser Val Trp Tyr Lys Cys Cys Glu Ser Gln Ser Leu Pro
 420 425 430

Gly Leu Ser Lys Val Tyr Phe Tyr Trp Ile Cys Arg Asp Ala Ala Ala
 435 440 445

Phe Glu Trp Phe Ala Asp Leu Leu Leu Ser Leu Glu Thr Gln Met Ser
 450 455 460

Glu Gln Gly Lys Ala His Leu Leu Ser Tyr His Ile Tyr Leu Thr Gly
 465 470 475 480

Trp Asp Glu Tyr Gln Ala Ile His Ile Ala Leu His Trp Asp Glu Ser
 485 490 495

Leu Asp Val Ile Thr Gly Leu Lys Gln Lys Thr Phe Tyr Gly Arg Pro
 500 505 510

Asn Trp Asn Glu Glu Phe Lys Gln Ile Ala Tyr Asn His Pro Ser Ser
 515 520 525

Ser Ile Gly Val Phe Phe Cys Gly Pro Lys Ala Met Ser Lys Thr Leu
 530 535 540

Gln Lys Met Cys Arg Leu Tyr Ser Ser Ser Asp Pro Arg Gly Val His
 545 550 555 560

Phe Tyr Tyr Asn Lys Glu Asn Phe
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<210> 6
 <211> 1707
 <212> DNA
 <213> Rattus norvegicus

<400> 6
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 ttttatacac gagttattct gggttccgca ttggcatggg cccgggcata tgcctgtgtc 180
 ctgaatttta actgcatgct aattctgtta cctgtcagtc ggaacttcgt ttactggtg 240
 agaggaacga gcgtgtgctg tagaggaccg tggagacggc aactagacaa aaacctcaag 300
 ttccacaagc tcgttgccca cgggatatgt gtaattcag ttatccacat tgtggcacac 360
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 gcgctttcca aacttggaac tgccccaagt gaaagctacc tcaatccggc ccgcaccttg 480
 tatacgggta caaccactca gctattaatg acagtctccg gaattactgg cctgggtgatc 540
 tctctgggctt tgatattgat catgacctct tcaactgagt ttatcaggca gtcctcttat 600

10

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caccatctg cagtcctgga acttcacatg aagaagcgtg acttcaagat ggcgcccgga   960
cagtacatct ttatccagtg cccatccatc tccccgctgg agtggcacc cttcactctc  1020
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<210> 7
 <211> 371
 <212> PRT
 <213> Homo sapiens

<400> 7

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Met Ala Gly Pro Arg Tyr Pro Val Ser Val Gln Gly Ala Ala Leu Val
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Gln Ile Lys Arg Leu Gln Thr Phe Ala Phe Ser Val Arg Trp Ser Asp
          20          25          30

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Gly Ser Asp Thr Phe Val Arg Arg Ser Trp Asp Glu Phe Arg Gln Leu
          35          40          45

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Lys Lys Thr Leu Lys Glu Thr Phe Pro Val Glu Ala Gly Leu Leu Arg
50          55          60

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Arg Ser Asp Arg Val Leu Pro Lys Leu Leu Asp Ala Pro Leu Leu Gly
65          70          75          80

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Arg Val Gly Arg Thr Ser Arg Gly Leu Ala Arg Leu Gln Leu Leu Glu
          85          90          95

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Thr Tyr Ser Arg Arg Leu Leu Ala Thr Ala Glu Arg Val Ala Arg Ser
 100 105 110
 Pro Thr Ile Thr Gly Phe Phe Ala Pro Gln Pro Leu Asp Leu Glu Pro
 115 120 125
 Ala Leu Pro Pro Gly Ser Arg Val Ile Leu Pro Thr Pro Glu Glu Gln
 130 135 140
 Pro Leu Ser Arg Ala Ala Gly Arg Leu Ser Ile His Ser Leu Glu Ala
 145 150 155 160
 Gln Ser Leu Arg Cys Leu Gln Pro Phe Cys Thr Gln Asp Thr Arg Asp
 165 170 175
 Arg Pro Phe Gln Ala Gln Ala Gln Glu Ser Leu Asp Val Leu Leu Arg
 180 185 190
 His Pro Ser Gly Trp Trp Leu Val Glu Asn Glu Asp Arg Gln Thr Ala
 195 200 205
 Trp Phe Pro Ala Pro Tyr Leu Glu Glu Ala Ala Pro Gly Gln Gly Arg
 210 215 220
 Glu Gly Gly Pro Ser Leu Gly Ser Ser Gly Pro Gln Phe Cys Ala Ser
 225 230 235 240
 Arg Ala Tyr Glu Ser Ser Arg Ala Asp Glu Leu Ser Val Pro Ala Gly
 245 250 255
 Ala Arg Val Arg Val Leu Glu Thr Ser Asp Arg Gly Trp Trp Leu Cys
 260 265 270
 Arg Tyr Gly Asp Arg Ala Gly Leu Leu Pro Ala Val Leu Leu Arg Pro
 275 280 285
 Glu Gly Leu Gly Ala Leu Leu Ser Gly Thr Gly Phe Arg Gly Gly Asp
 290 295 300
 Asp Pro Ala Gly Glu Ala Arg Gly Phe Pro Glu Pro Ser Gln Ala Thr
 305 310 315 320
 Ala Pro Pro Pro Thr Val Pro Thr Arg Pro Ser Pro Gly Ala Ile Gln
 325 330 335
 Ser Arg Cys Cys Thr Val Thr Arg Arg Ala Leu Glu Arg Arg Pro Arg
 340 345 350
 Arg Gln Gly Arg Pro Arg Gly Cys Val Asp Ser Val Pro His Pro Thr
 355 360 365

Thr Glu Gln
370

<210> 8
<211> 1116
<212> DNA
<213> Homo sapiens

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<210> 9
<211> 349
<212> PRT
<213> Mus musculus

<400> 9

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Gln Met Asp Arg Leu Gln Thr Phe Ala Phe Ser Val Cys Trp Ser Asp
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35 40 45

Gln Lys Thr Leu Lys Lys Thr Phe Pro Val¹³ Glu Ala Gly Leu Leu Arg
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 Arg Ser Glu Gln Val Leu Pro Lys Leu Pro Asp Ala Pro Leu Leu Thr
 65 70 75 80
 Arg Arg Gly His Thr Gly Arg Gly Leu Val Arg Leu Arg Leu Leu Asp
 85 90 95
 Thr Tyr Val Gln Ala Leu Leu Ala Thr Ser Glu His Ile Leu Arg Ser
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 Ser Ala Leu His Gly Phe Phe Val Pro Lys Pro Leu Asp Leu Glu Pro
 115 120 125
 Met Leu Pro Pro Gly Ser Leu Val Ile Leu Pro Thr Pro Glu Glu Pro
 130 135 140
 Leu Ser Gln Pro Arg Gly Ser Leu Asp Ile His Ser Leu Glu Ala Gln
 145 150 155 160
 Ser Ile Pro Cys Val Gln Pro Phe His Thr Leu Asp Ile Arg Asp Arg
 165 170 175
 Pro Phe His Thr Lys Ala Gln Glu Ile Leu Asp Ile Leu Leu Arg His
 180 185 190
 Pro Ser Gly Trp Trp Leu Val Glu Asn Lys Asp Gln Gln Val Ala Trp
 195 200 205
 Phe Pro Ala Pro Tyr Leu Glu Glu Val Ala Thr Cys Gln Gly Gln Glu
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 Ser Gly Leu Ala Leu Gln Gly Ser Gly Arg Gln Phe Cys Thr Thr Gln
 225 230 235 240
 Ala Tyr Glu Gly Ser Arg Ser Asp Glu Leu Ser Val Pro Ser Gly Ala
 245 250 255
 Arg Val His Val Leu Glu Thr Ser Asp Arg Gly Trp Trp Leu Cys Arg
 260 265 270
 Tyr Asn Gly Arg Thr Gly Leu Leu Pro Ala Met Ser Leu Gln Pro Glu
 275 280 285
 Gly Leu Gly Ser Leu Leu Gly Arg Pro Gly Phe Pro Asp Ser Ala Gly
 290 295 300
 Ala Asp Lys Val Ala Glu Asp Arg Thr Ile Pro Pro Val Val Pro Thr
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 Arg Pro Cys Met Ser Ala Ile Gln Ser Arg Cys Cys Ser Ile Thr Arg

325

330¹⁴

335

Arg Ala Leu Gly Gln Glu Gln Gly Thr Arg Val Pro Arg
 340 345

<210> 10
 <211> 1050
 <212> DNA
 <213> Mus musculus

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<210> 11
 <211> 482
 <212> PRT
 <213> Homo sapiens

<400> 11

Met Ala Ser Leu Gly Asp Leu Val Arg Ala Trp His Leu Gly Ala Gln
 1 5 10 15

Ala Val Asp Arg Gly Asp Trp Ala Arg Ala Leu His Leu Phe Ser Gly
 20 25 30

Val Pro Ala Pro Pro Ala Arg Leu Cys Phe Asn Ala Gly Cys Val His
 35 40 45

Leu Leu Ala Gly Asp Pro Glu Ala Ala Leu Arg Ala Phe Asp Gln Ala
 50 55 60 15
 Val Thr Lys Asp Thr Cys Met Ala Val Gly Phe Phe Gln Arg Gly Val
 65 70 75 80
 Ala Asn Phe Gln Leu Ala Arg Phe Gln Glu Ala Leu Ser Asp Phe Trp
 85 90 95
 Leu Ala Leu Glu Gln Leu Arg Gly His Ala Ala Ile Asp Tyr Thr Gln
 100 105 110
 Leu Gly Leu Arg Phe Lys Leu Gln Ala Trp Glu Val Leu His Asn Val
 115 120 125
 Ala Ser Ala Gln Cys Gln Leu Gly Leu Trp Thr Glu Ala Ala Ser Ser
 130 135 140
 Leu Arg Glu Ala Met Ser Lys Trp Pro Glu Gly Ser Leu Asn Gly Leu
 145 150 155 160
 Asp Ser Ala Leu Asp Gln Val Gln Arg Arg Gly Ser Leu Pro Pro Arg
 165 170 175
 Gln Val Pro Arg Gly Glu Val Phe Arg Pro His Arg Trp His Leu Lys
 180 185 190
 His Leu Glu Pro Val Asp Phe Leu Gly Lys Ala Lys Val Val Ala Ser
 195 200 205
 Ala Ile Pro Asp Asp Gln Gly Trp Gly Val Arg Pro Gln Gln Pro Gln
 210 215 220
 Gly Pro Gly Ala Asn His Asp Ala Arg Ser Leu Ile Met Asp Ser Pro
 225 230 235 240
 Arg Ala Gly Thr His Gln Gly Pro Leu Asp Ala Glu Thr Glu Val Gly
 245 250 255
 Ala Asp Arg Cys Thr Ser Thr Ala Tyr Gln Glu Gln Arg Pro Gln Val
 260 265 270
 Glu Gln Val Gly Lys Gln Ala Pro Leu Ser Pro Gly Leu Pro Ala Met
 275 280 285
 Gly Gly Pro Gly Pro Gly Pro Cys Glu Asp Pro Ala Gly Ala Gly Gly
 290 295 300
 Ala Gly Ala Gly Gly Ser Glu Pro Leu Val Thr Val Thr Val Gln Cys
 305 310 315 320
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<210> 12
<211> 1452
<212> DNA
<213> Homo sapiens
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	tgcttcaacg cgggctgcgt gcacctgctg gccggggacc ccgaggccgc gctgcgggca	180
	tttgaccaag ccgtgaccaa ggacacctgc atggcggttg gcttcttcca gcgaggagt	240
	gccaacttcc agctggcaag gttccaggag gctctgtctg acttctggct ggccctggag	300
	cagctgaggg gccacgctgc catcgactac acgcagctgg gcctgcgggt caagctgcaa	360
	gcctggggagg tgctacacaa tgtggcgctg gcacagtgcc agctggggct ctggacagag	420
	gcggccagca gcctaaggga ggccatgtcc aagtggccgg aggggtccct gaatggcctg	480
	gactcagccc tggaccaagt gcagagacgg ggctcactgc cgccacggca ggtccccagg	540
	ggcgaggtct tccggcccca ccggtggcac ctgaagcact tggagcccgt ggatttcctg	600

17

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agagctggca cccaccaggg cccctcgat gcagagacag aggtcggtgc tgaccgctgc 780
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gatcagccct aa 1452

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<210> 13
 <211> 444
 <212> PRT
 <213> Mus musculus

<400> 13

Met Ser Ser Leu Gly Asp Gln Ile Arg Asp Trp His Arg Gly Val Leu
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Ala Val Ala Arg Glu Asp Trp Asp Ser Ala Leu Cys Phe Phe Ser Asp
 20 25 30

Val Arg Glu Pro Leu Ala Arg Met Tyr Phe Asn Arg Gly Cys Val His
 35 40 45

Leu Met Ala Gly Asp Pro Glu Ala Ala Leu Arg Ala Phe Asp Gln Ala
 50 55 60

Val Thr Lys Asp Thr Cys Met Ala Val Gly Phe Leu Gln Arg Gly Val
 65 70 75 80

Ala Asn Phe Gln Leu Gln Arg Phe Gln Glu Ala Val Ser Asp Phe Gln
 85 90 95

Leu Ala Leu Ala Gln Leu Arg Asp Asn Ala Val Ile Asp Tyr Thr Gln
 100 105 110

Leu Gly Leu Asn Phe Lys Leu Gln Ala Trp Glu Val Leu Tyr Asn Met
 115 120 125

18

Ala Ser Ala Gln Cys Gln Ala Gly Leu Trp Thr Lys Ala Ala Asn Thr
 130 135 140
 Leu Val Glu Ala Ile Ser Lys Trp Pro Glu Gly Ala Gln Asp Ile Leu
 145 150 155 160
 Asp Ile Ala Met Asp Lys Val Gln Lys Gln Val Pro Leu Gln Leu Gln
 165 170 175
 Gln Val Pro Lys Gly Glu Val Phe Gln Pro Pro Arg Arg Tyr Leu Lys
 180 185 190
 His Leu Glu Pro Met Asp Phe Leu Gly Lys Ala Lys Val Val Ala Ser
 195 200 205
 Val Ile Pro Asp Asp His Asn Ala Gln Pro Gln Gln Arg Ser Gln Ala
 210 215 220
 Glu His Ala Gly His Gln Pro Ser Ser Ser Met Cys Lys Arg Val Leu
 225 230 235 240
 Ser Thr Thr Gly Gly His Thr Ser Pro Gly Leu Tyr Asp Ser Leu Leu
 245 250 255
 Ala Ser Arg Arg Pro Gly Pro Gly Pro Ser Glu Val Ser Ser Gly Ser
 260 265 270
 Glu Gly Ala Ala Thr Lys Asp Pro Glu Ser Leu Val Thr Val Thr Val
 275 280 285
 Gln Cys His Phe Thr Val Pro Leu Lys Val Pro Arg Gly Thr Gly Leu
 290 295 300
 Ser Ser Phe Gln Thr Leu Leu Ala Gln Ala Leu Leu His Gln Thr Gln
 305 310 315 320
 Thr Gly Gln Leu Ser Tyr Lys Ala Pro Gly Glu Glu Arg Ser Trp Ile
 325 330 335
 Pro Ile Ser Thr Glu Glu Ser Leu Gln Ser Ile Trp Arg Asn Val Pro
 340 345 350
 Val Gly Pro Gly Gly Leu Gln Leu Gln Cys Gln Gly Val Trp Gly Arg
 355 360 365
 Pro Val Leu Tyr Gln Val Val Ala Gln Tyr Asn Tyr Arg Ala Gln Arg
 370 375 380
 Pro Glu Asp Leu Asp Phe His Gln Gly Asp Thr Val Asp Val Leu Cys
 385 390 395 400

Glu Val Asp Glu Ala Trp Leu Glu Gly His Arg Asp Gly Cys Val Gly
 405 410 415

Ile Phe Pro Lys Cys Phe Val Val Pro Ala Gly Ala Tyr Val Glu Ala
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 435 440

<210> 14
 <211> 1335
 <212> DNA
 <213> Mus musculus

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 cctggtccag gcccctctga agtttcctca ggatctgagg gagcagctac aaaggaccct 840
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 cgtgcccaaa gaccggagga tttggacttc caccaagggg acacggtgga tgtcctgtgt 1200
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 ggagaccaga actag 1335

<210> 15
 <211> 526
 <212> PRT
 <213> Homo sapiens

20

<400> 15

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 1 5 10 15

Ala Asp Lys Lys Asp Trp Lys Gly Ala Leu Asp Ala Phe Ser Ala Val
 20 25 30

Gln Asp Pro His Ser Arg Ile Cys Phe Asn Ile Gly Cys Met Tyr Thr
 35 40 45

Ile Leu Lys Asn Met Thr Glu Ala Glu Lys Ala Phe Thr Arg Ser Ile
 50 55 60

Asn Arg Asp Lys His Leu Ala Val Ala Tyr Phe Gln Arg Gly Met Leu
 65 70 75 80

Tyr Tyr Gln Thr Glu Lys Tyr Asp Leu Ala Ile Lys Asp Leu Lys Glu
 85 90 95

Ala Leu Ile Gln Leu Arg Gly Asn Gln Leu Ile Asp Tyr Lys Ile Leu
 100 105 110

Gly Leu Gln Phe Lys Leu Phe Ala Cys Glu Val Leu Tyr Asn Ile Ala
 115 120 125

Phe Met Tyr Ala Lys Lys Glu Glu Trp Lys Lys Ala Glu Glu Gln Leu
 130 135 140

Ala Leu Ala Thr Ser Met Lys Ser Glu Pro Arg His Ser Lys Ile Asp
 145 150 155 160

Lys Ala Met Glu Cys Val Trp Lys Gln Lys Leu Tyr Glu Pro Val Val
 165 170 175

Ile Pro Val Gly Arg Leu Phe Arg Pro Asn Glu Arg Gln Val Ala Gln
 180 185 190

Leu Ala Lys Lys Asp Tyr Leu Gly Lys Ala Thr Val Val Ala Ser Val
 195 200 205

Val Asp Gln Asp Ser Phe Ser Gly Phe Ala Pro Leu Gln Pro Gln Ala
 210 215 220

Ala Glu Pro Pro Pro Arg Pro Lys Thr Pro Glu Ile Phe Arg Ala Leu
 225 230 235 240

Ile Gly Glu Ala His Arg Val Leu Phe Gly Phe Val Pro Glu Thr Lys
 245 250 255

Ile Glu Leu Gln Val Met Pro Gly Asn Ile Val Phe Val Leu Lys Lys
 260 265 270

21

Gly Asn Asp Asn Trp Ala Thr Val Met Phe Asn Gly Gln Lys Gly Leu
 275 280 285
 Val Pro Cys Asn Tyr Leu Glu Pro Val Glu Leu Arg Ile His Pro Gln
 290 295 300
 Gln Gln Pro Gln Glu Glu Ser Ser Pro Gln Ser Asp Ile Pro Ala Pro
 305 310 315 320
 Pro Ser Ser Lys Ala Pro Gly Arg Pro Gln Leu Ser Pro Gly Gln Lys
 325 330 335
 Gln Lys Glu Glu Pro Lys Glu Val Lys Leu Ser Val Pro Met Pro Tyr
 340 345 350
 Thr Leu Lys Val His Tyr Lys Tyr Thr Val Val Met Lys Thr Gln Pro
 355 360 365
 Gly Leu Pro Tyr Ser Gln Val Arg Asp Met Val Ser Lys Lys Leu Glu
 370 375 380
 Leu Arg Leu Glu Gln Thr Lys Leu Ser Tyr Arg Pro Arg Asp Ser Asn
 385 390 395 400
 Glu Leu Val Pro Leu Ser Glu Asp Ser Met Lys Asp Ala Trp Gly Gln
 405 410 415
 Val Lys Asn Tyr Cys Leu Thr Leu Trp Cys Glu Asn Thr Val Gly Asp
 420 425 430
 Gln Gly Phe Pro Asp Glu Pro Lys Glu Ser Glu Lys Ala Asp Ala Asn
 435 440 445
 Asn Gln Thr Thr Glu Pro Gln Leu Lys Lys Gly Ser Gln Val Glu Ala
 450 455 460
 Leu Phe Ser Tyr Glu Ala Thr Gln Pro Glu Asp Leu Glu Phe Gln Glu
 465 470 475 480
 Gly Asp Ile Ile Leu Val Leu Ser Lys Val Asn Glu Glu Trp Leu Glu
 485 490 495
 Gly Glu Cys Lys Gly Lys Val Gly Ile Phe Pro Lys Val Phe Val Glu
 500 505 510
 Asp Cys Ala Thr Thr Asp Leu Glu Ser Thr Arg Arg Glu Val
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<210> 16
 <211> 1581
 <212> DNA

22

<213> Homo sapiens

<400> 16

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ttcaacattg gctgcatgta cactatcctg aagaacatga ctgaagcaga gaaggccttt      180
accagaagca ttaaccgaga caagcacttg gcagtggctt acttccaacg agggatgctc      240
tactaccaga cagagaaata tgatttggct atcaaagacc ttaaagaagc cttgattcag      300
cttcgagggg accagctgat agactataag atcctggggc tccagttcaa gctgtttgcc      360
tgtgaggtgt tatataacat tgctttcatg tatgccaaag aggaggaatg gaaaaaagct      420
gaagaacagt tagcattggc cacgagcatg aagtctgagc ccagacattc caaaatcgac      480
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aggctgtttc gaccaaata gagacaagtg gctcagctgg ccaagaagga ttacctaggc      600
aaggcaacgg tcgtggcatc tgtgggtggat caagacagtt tctctgggtt tgcccctctg      660
caaccacagg cagctgagcc tccaccaga cggaaaacc cagagatctt cagggtctctg      720
gaaggggagg ctaccgtgt gctatttggg tttgtgcctg agacaaaaga agagctccag      780
gtcatgccag ggaacattgt ctttgtcttg aagaagggca atgataactg ggccacggtc      840
atgttcaacg ggcagaaggg gcttgttccc tgcaactacc ttgaaccagt tgagctgcgg      900
atccaccctc agcagcagcc ccaggaggaa agctctccgc agtccgacat cccagctcct      960
cctagtcca aagcccctgg aagaccccag ctgtcaccag gccagaaaca aaaagaagag     1020
cctaaggaag tgaagctcag tgttcccatg ccctacacac tcaagggtgca ctacaagtac     1080
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<210> 17

<211> 525

<212> PRT

<213> Mus musculus

<400> 17

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:

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 Gln Asp Pro His Ser Arg Ile Cys Phe Asn Ile Gly Cys Val Asn Thr
 35 40 45
 Ile Leu Glu Asn Leu Gln Ala Ala Glu Gln Ala Phe Thr Lys Ser Ile
 50 55 60
 Asn Arg Asp Lys His Ser Ala Val Ala Tyr Phe Gln Arg Gly Met Leu
 65 70 75 80
 Tyr Tyr Arg Met Glu Lys Tyr Asp Leu Ala Ile Lys Asp Leu Lys Glu
 85 90 95
 Ala Leu Thr Gln Leu Arg Gly Asn Gln Leu Ile Asp Tyr Lys Ile Leu
 100 105 110
 Gly Leu Gln Phe Lys Leu Phe Ala Cys Glu Val Leu Tyr Asn Ile Ala
 115 120 125
 Leu Met His Ala Lys Lys Glu Glu Trp Lys Lys Ala Glu Glu Gln Leu
 130 135 140
 Ala Leu Ala Thr Asn Met Lys Ser Glu Pro Arg His Ser Lys Ile Asp
 145 150 155 160
 Lys Ala Met Glu Ser Ile Trp Lys Gln Lys Leu Phe Glu Pro Val Val
 165 170 175
 Ile Pro Val Gly Arg Leu Phe Arg Pro Asn Glu Arg Gln Val Ala Gln
 180 185 190
 Leu Ala Lys Lys Asp Tyr Leu Gly Lys Ala Thr Val Val Ala Ser Val
 195 200 205
 Val His Gln Asp Asn Phe Ser Gly Phe Ala Pro Leu Gln Pro Gln Ser
 210 215 220
 Ala Glu Pro Pro Pro Arg Pro Lys Thr Pro Glu Ile Phe Arg Ala Leu
 225 230 235 240
 Glu Gly Glu Ala His Arg Val Leu Phe Gly Phe Val Pro Glu Thr Pro
 245 250 255
 Glu Glu Leu Gln Val Met Pro Gly Asn Ile Val Phe Val Leu Lys Lys
 260 265 270
 Gly Ser Asp Asn Trp Ala Thr Val Met Phe Asn Gly Gln Lys Gly Leu
 275 280 285
 Val Pro Cys Asn Tyr Leu Glu Pro Val Glu Leu Arg Ile His Pro Gln

290 295 24 300
 Ser Gln Pro Gln Glu Asp Thr Ser Pro Glu Ser Asp Ile Pro Pro Pro
 305 310 315 320
 Pro Asn Ser Ser Pro Pro Gly Arg Leu Gln Leu Ser Pro Gly His Lys
 325 330 335
 Gln Lys Glu Pro Lys Glu Leu Lys Leu Ser Val Pro Met Pro Tyr Met
 340 345 350
 Leu Lys Val His Tyr Lys Tyr Thr Val Val Met Glu Thr Arg Leu Gly
 355 360 365
 Leu Pro Tyr Ser Gln Leu Arg Asn Met Val Ser Lys Lys Leu Ala Leu
 370 375 380
 Ser Pro Glu His Thr Lys Leu Ser Tyr Arg Arg Arg Asp Ser His Glu
 385 390 395 400
 Leu Leu Leu Leu Ser Glu Glu Ser Met Lys Asp Ala Trp Gly Gln Val
 405 410 415
 Lys Asn Tyr Cys Leu Thr Leu Trp Cys Glu His Thr Val Gly Asp Gln
 420 425 430
 Gly Leu Ile Asp Glu Pro Ile Gln Arg Glu Asn Ser Asp Ala Ser Lys
 435 440 445
 Gln Thr Thr Glu Pro Gln Pro Lys Glu Gly Thr Gln Val Val Ala Ile
 450 455 460
 Phe Ser Tyr Glu Ala Ala Gln Pro Glu Asp Leu Glu Phe Val Glu Gly
 465 470 475 480
 Asp Val Ile Leu Val Leu Ser His Val Asn Glu Glu Trp Leu Glu Gly
 485 490 495
 Glu Cys Lys Gly Lys Val Gly Ile Phe Pro Lys Ala Phe Val Glu Gly
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 515 520 525

<210> 18
 <211> 1578
 <212> DNA
 <213> Mus musculus

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25

ttcaacatag gctgctgaa caccatcctg gaaaacttgc aggcagccga gcaggccttc	180
accaaaaagca tcaacagaga caagcactct gcagtggcct acttccagag aggaatgctc	240
tactacagaa tggagaagta cgaccttgct atcaaagacc ttaaagaggc cttgacgcag	300
cttcgtggga accagctgat agactacaag atcctggggc tgcagttcaa gctgtttgcc	360
tgtgaggtat tgtacaatat tgctctcatg catgccaaaga aagaggaatg gaagaaagca	420
gaagagcagt tggcattggc aaccaacatg aagtccgagc ccaggcattc caagatcgac	480
aaggccatgg agagcatctg gaagcagaag ctgttcgagc ccgtggtgat ccctgtgggt	540
cggctgttcc gtccaaatga gaggcagggtg gctcagctgg ccaaaaagga ctatctgggc	600
aaggctacgg ttgtagcatc tgtggttcac caagacaact tttctggctt cggccctctg	660
cagccgcagt cagcagagcc tcctcccaga cccaaaaccc cagaaatctt cagggtctctg	720
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gtcatgcctg ggaacatcgt ctttgtcttg aagaagggca gtgataactg ggccacagtc	840
atgttcaatg gacagaagggt gctgtcccc tgcaactacc tggagccagt tgagcttcgg	900
attcaccctc agtcgcagcc ccaggaagat acctctccag aatctgatat tccaccacct	960
cctaattcta gtcccccagg aagactccag ttgtcaccag gtcacaagca aaaagagccc	1020
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attcccagag aagtctag	1578

<210> 19
 <211> 390
 <212> PRT
 <213> Homo sapiens
 <400> 19

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 20 25 30

Ile Asp Leu Ser Glu Lys Val Val Tyr Arg Arg Phe Thr Glu Ile Tyr
 35 40 45

26

Glu Phe His Lys Thr Leu Lys Glu Met Phe Pro Ile Glu Ala Gly Ala
 50 55 60
 Ile Asn Pro Glu Asn Arg Ile Ile Pro His Leu Pro Ala Pro Lys Trp
 65 70 75 80
 Phe Asp Gly Gln Arg Ala Ala Glu Asn Arg Gln Gly Thr Leu Thr Glu
 85 90 95
 Tyr Cys Gly Thr Leu Met Ser Leu Pro Thr Lys Ile Ser Arg Cys Pro
 100 105 110
 His Leu Leu Asp Phe Phe Lys Val Arg Pro Asp Asp Leu Lys Leu Pro
 115 120 125
 Thr Asp Asn Gln Thr Lys Lys Pro Glu Thr Tyr Leu Met Pro Lys Asp
 130 135 140
 Gly Lys Ser Thr Ala Thr Asp Ile Thr Gly Pro Ile Ile Leu Gln Thr
 145 150 155 160
 Tyr Arg Ala Ile Ala Asn Tyr Glu Lys Thr Ser Gly Ser Glu Met Ala
 165 170 175
 Leu Ser Thr Gly Asp Val Val Glu Val Val Glu Lys Ser Glu Ser Gly
 180 185 190
 Trp Trp Phe Cys Gln Met Lys Ala Lys Arg Gly Trp Ile Pro Ala Ser
 195 200 205
 Phe Leu Glu Pro Leu Asp Ser Pro Asp Glu Thr Glu Asp Pro Glu Pro
 210 215 220
 Asn Tyr Ala Gly Glu Pro Tyr Val Ala Ile Lys Ala Tyr Thr Ala Val
 225 230 235 240
 Glu Gly Asp Glu Val Ser Leu Leu Glu Gly Glu Ala Val Glu Val Ile
 245 250 255
 His Lys Leu Leu Asp Gly Trp Trp Val Ile Arg Lys Asp Asp Val Thr
 260 265 270
 Ile Tyr Phe Pro Ser Met Tyr Leu Gln Lys Ser Gly Gln Asp Val Ser
 275 280 285
 Gln Ala Gln Arg Gln Ile Lys Arg Gly Ala Pro Pro Arg Arg Ser Ser
 290 295 300
 Ile Arg Asn Ala His Ser Ile His Gln Arg Ser Arg Lys Arg Leu Ser
 305 310 315 320

Gln Asp Ala Tyr Arg Arg Asn Ser Val Arg Phe Leu Gln Gln Arg Arg
 325 330 335
 Arg Gln Ala Arg Pro Gly Pro Gln Ser Pro Gly Ser Pro Leu Glu Glu
 340 345 350
 Glu Arg Gln Thr Gln Arg Ser Lys Pro Gln Pro Ala Val Pro Pro Arg
 355 360 365
 Pro Ser Ala Asp Leu Ile Leu Asn Arg Cys Ser Glu Ser Thr Lys Arg
 370 375 380
 Lys Leu Ala Ser Ala Val
 385 390

<210> 20
 <211> 1173
 <212> DNA
 <213> Homo sapiens

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 taccggcgct tcaccgagat ctacgagttc cataaaacct taaaagaaat gttccctatt 180
 gaggcagggg cgatcaatcc agagaacagg atcatcccc acctcccagc tcccaagtgg 240
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